

A NON-MARINE OSTRACOD FAUNA FROM THE COAL MEASURES OF DURHAM AND NORTHUMBERLAND

by JOHN E. POLLARD

ABSTRACT. The occurrence and ostracod fauna of the Hopkins Band, Lower *Anthraconaia modiolaris* Zone, of the Lower Coal Measures of Northumberland and Durham are described. In this Band the ostracod *Geisina arcuata* is associated with five species of *Carbonita*, newly recorded, and variants of the non-marine lamelli-branches *Anthracostia regularis*, *Carbonicola oslancis*, *Naiadites productus*, and *Anthraconaia modiolaris*. A vertical sequence of six faunal phases is recognized in this Band and is compared with that previously recorded from an equivalent stratigraphical horizon in the Yorkshire Coal Measures.

Vertical changes in the number of ostracod species and number of moults present in the Hopkins Band are recorded and explained in terms of the changing conditions in the environment of deposition. Certain ecological requirements of the ostracods are suggested.

In the systematic description of the fauna a lectotype for *Geisina arcuata* and a new species *Carbonita claripunctata* are proposed. The species *Carbonita humilis*, *C. evelinae*, *C. pmogens*, and *C. inflata* are briefly described and their morphology and stratigraphical distribution discussed.

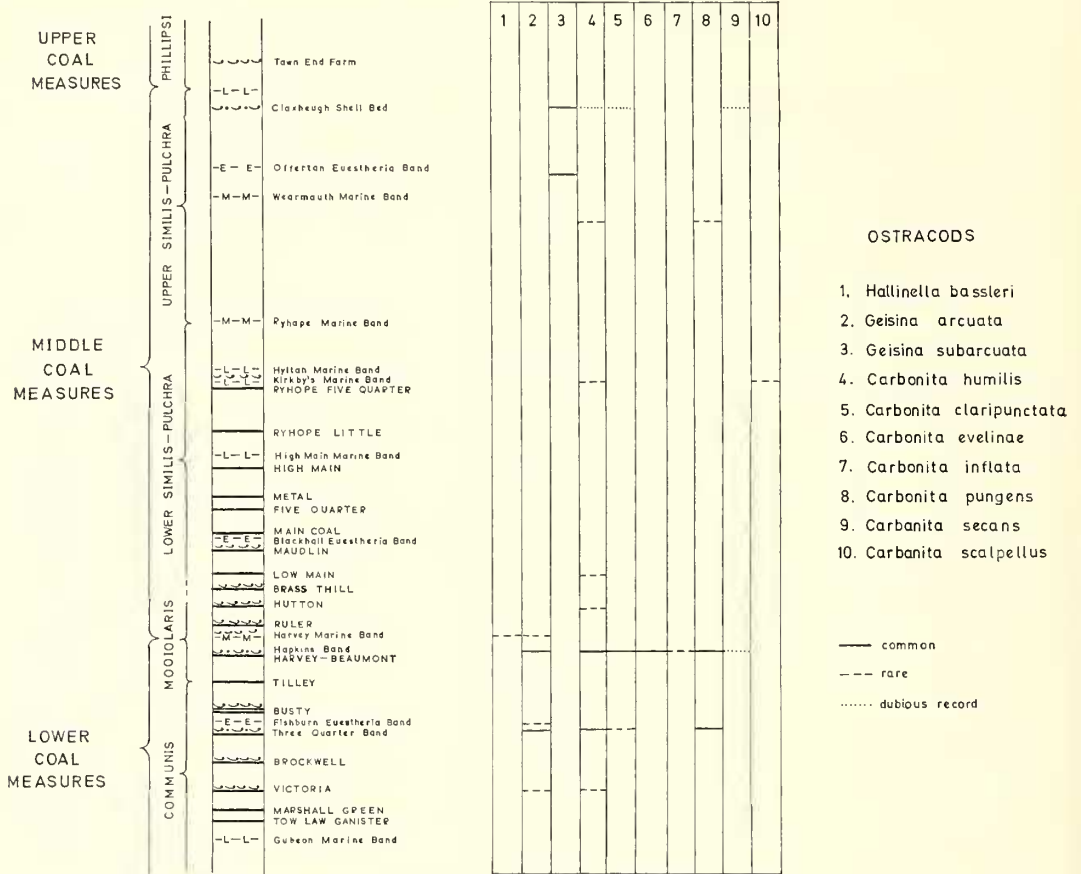
Lectotypes for *Carbonita agnes*, *C. evelinae*, *C. humilis*, *C. inflata*, *C. pmogens*, and *C. rankiniana* are designated by F. W. Anderson in a postscript.

DESPITE the profusion of non-marine ostracods at many horizons within the British Coal Measures, these fossils have received little attention since the latter half of the nineteenth century. The earliest descriptions of Coal Measures ostracods were by Bean (1836) from Northumberland and Durham, and Murchison (1839) from North Staffordshire, but the majority of known species have been described and named by Jones (1870), and Jones and Kirkby (1867, 1879, 1886*a*, 1886*b*, and 1890). The Carboniferous ostracod faunas of Scotland were revised by Latham (1932) in the light of the then current American work (i.e. Ulrich and Bassler 1906, 1908; Harlton 1927, 1928; Knight 1928; and Roundy 1926), but since then little has been published on British Coal Measure species, except for occasional lists and records given in the publications of the Geological Survey.

In the Coal Measures there is a fairly sharp distinction between marine and non-marine associations of ostracods. Ostracods are relatively rare in marine and *Lingula* bands in which only *Hollinella bassleri*, *Paraparchites*, and *Cypridina* occur with any frequency. Ramsbottom (1952) recorded a unique fauna from the Cefn Coed Marine Band of South Wales which included the genera *Amphiissites*, *Cornigella*, *Cypridina*, *Kirkbya*, *Knightina* and *Roundyella*, as well as *Hollinella*. All these genera are common in the American Pennsylvanian. Although non-marine assemblages of ostracods are of much commoner occurrence than marine ones, and occur in greater profusion, the number of genera represented is smaller. *Geisina* and *Carbonita* are the only common genera, and it is with these that this paper is concerned.

The ostracods that have been recorded by various authors from horizons in the Northumberland and Durham Coal Measures are shown in text-fig. 1. Apart from one specimen of *Hollinella bassleri*, recorded by Armstrong and Price (1953) from the

mid-*modiolaris* or Harvey Marine Band, all the others are species of the non-marine genera *Geisina* and *Carbonita*. Most of these records are of a few specimens of one or two species found at isolated localities and horizons, but that of the Hopkins Band in the Lower *A. modiolaris* Zone is of a rich fauna which occurs at the same horizon throughout much of the coalfield. The purpose of this paper is to describe the ostracod fauna of this Band in detail, and to relate its major vertical changes to the changing conditions in its depositional environment.



TEXT-FIG. 1. Ostracod species recorded from the Coal Measures of Northumberland and Durham.

THE OCCURRENCE AND FAUNA OF THE HOPKINS BAND

Definition. The Hopkins Band, or Hopkins Shell Bed, was first described by Hopkins (1927) as 'The Ostracod Band' above the Beaumont or Harvey Seam of the Northumberland and Durham Coalfield, and was named after him by Carruthers (1930, p. 69). A complete definition was given by Hopkins (1928, p. 6):

This Band is unique in the coalfield as wherever it is found it shows a constant threefold division.

(3) An upper division composed of *Carbonicola* and *Naiadites*.

- (2) A middle division composed of *Spirorbis* and a few Carbonicolae, and
- (1) A basal division composed entirely of ostracods.

It is not the presence of the ostracod '*Beyrichia*' *arcuata* (Bean) that makes it distinctive but the assemblage and order of deposition of the ostracods, annelids and mussels.

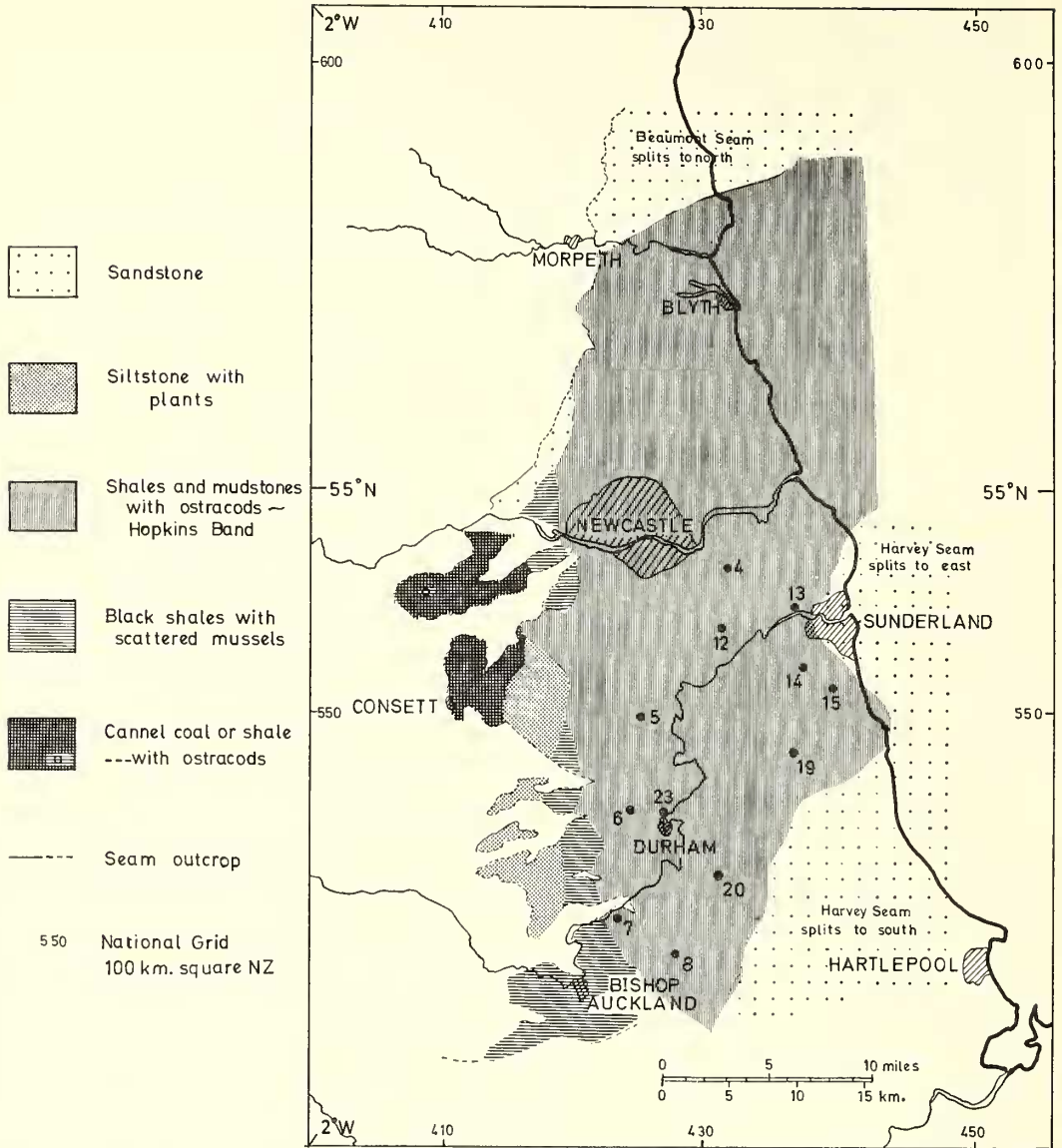
A complete account of subsequent reference to this Band was given by Hopkins (1960) in the Lexique Stratigraphique International.

Other ostracod–mussel associations at a corresponding stratigraphical horizon in the *modiolaris* Zone were later described from many other British Coalfields; for instance, from Scotland (Leitch, Absalom, and Henderson 1937), from Lancashire and Yorkshire (Wright 1931; Eagar 1961), from North Wales (Wood 1937), and from North Staffordshire (Melville 1946). The importance of the Hopkins Band is that it was the first band of its type to be described, is the best known, and is probably the type horizon for the common Coal Measure ostracod *Geisina arcuata* (Bean).

Occurrence and stratigraphy. Text-fig. 2 shows the geographical distribution of the different sediment types associated with the Hopkins Band in the roof strata of the Harvey–Beaumont Seam, as mapped from borehole information and underground evidence. The Band can be traced northwards from Ferryhill in County Durham to Blyth in Northumberland, and eastwards in County Durham from Burnopfield to Sunderland, covering an area of approximately 450 square miles. Throughout this area the stratigraphy of the Band is consistently as shown in text-fig. 3, although the thickness of the fossiliferous strata may vary from 6 in. to 3 ft. 6 in. Magraw, Clarke, and Smith (1963, p. 162) recorded an association of ostracods and mussels in shales above the Harvey Seam in Offshore Bore No. 1, four and a half miles east of Blackhall Colliery but the stratigraphy is not typical of the Hopkins Band.

The normal stratigraphic sequence of the Hopkins Band shows that the Harvey–Beaumont seam is overlain either by a bed of ankeritic mudflake conglomerate between a quarter and six inches in thickness, or else by a black carbonaceous shale. A black shale with between 5% and 8% of organic carbon, rich in macroscopic plant remains, ostracods, and *Naiadites* succeeds the conglomerate or its lateral equivalent. At the top of this shale is a densely packed coquina of ostracods, *Naiadites*, and *Spirorbis*, which I have called the *Geisina* Phase. This is equivalent to the Hopkins (1928) division 1 of the Band. Above the *Geisina* Phase, the lithology changes abruptly (text-fig. 3) to a laminated grey shaly-mudstone with less than 1% organic carbon. At this level the population density of the ostracod fauna declines and the non-marine lamellibranch *Carbonicola* appears. This is Hopkins division 2. Clay ironstone nodules and bands appear in the upper part of the grey mudstone, and the lamellibranchs *Anthracosia* and *Naiadites* replace *Carbonicola*, as in Hopkins division 3. A fine siltstone succeeds the mudstone and the fauna then disappears.

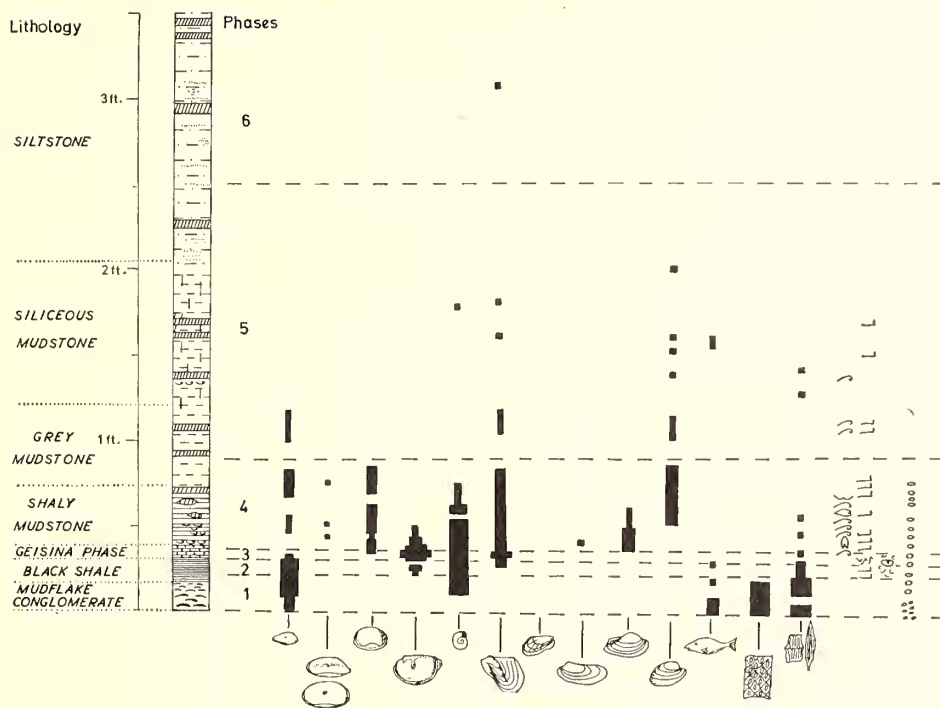
Faunal composition. The fossils recorded from the Hopkins Band prior to the present study have been listed by Hopkins (1960). The present work reveals a more extensive fauna than was previously known, and a more detailed faunal sequence, as shown in text-fig. 3. Five species of the ostracod genus *Carbonita*, namely *C. humilis* (Jones and Kirkby), *C. evelinae* (Jones), *C. pungens* (Jones and Kirkby), *C. inflata* (Jones and Kirkby), and *C. claripunctata* sp. nov., are recorded from this band for the first time in association with *Geisina arcuata* (Bean).



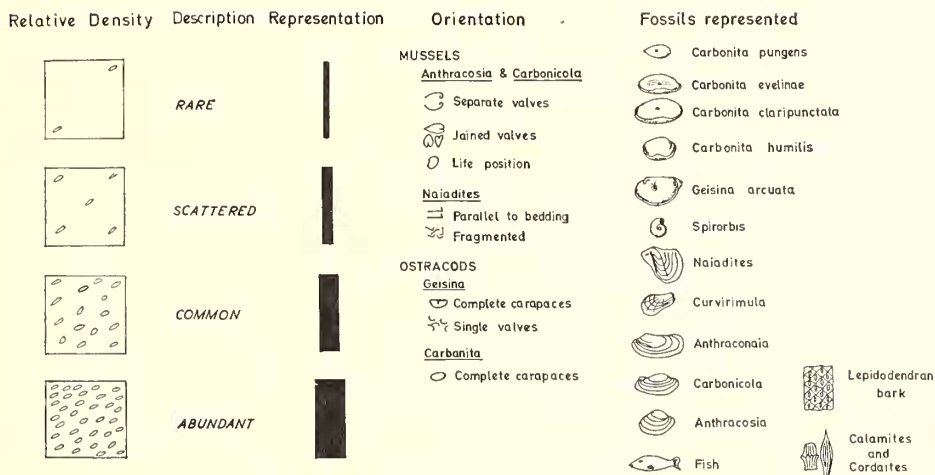
TEXT-FIG. 2. Distribution of the sediment types in the immediate roof-strata of the Beaumont-Harvey Seam of the Northumberland and Durham Coalfield. (The large black spots and adjacent numbers refer to the localities mentioned in the text and in Table 5.)

Most of the non-marine lamellibranchs recorded by Hopkins have been found and the overall mussel fauna is of the *oslaucis-regularis* type (Calver 1956), which is typical of horizons below the mid-*modiolaris* Marine Band. *Naiadites* is represented by variants of the *N. triangularis-productus* group and carinate forms of *N. carinatus-flexuosus*. The specimens of *Carbonicola* are mainly variants of *C. oslaucis* with a low height-length ratio, but smaller, more orbicular forms close to *C. venusta* are fairly common. The

TYPE SECTION : BEARPARK locality 6



KEY TO FAUNAL PHASE DIAGRAM



TEXT-FIG. 3. Faunal phases of the Hopkins Band at the type-locality, Bearpark Colliery, County Durham.

upper part of the Band is dominated by *Anthracosia regularis* with rare variants towards *A. cf. aquilina* and *A. cf. ovum*. Rare specimens of *Anthraconaia* also occur and these are mainly *A. modiolaris* or forms close to *A. robertsoni* and *A. williamsoni*.

Fish remains are confined to the lowest black shale, where scales and spines of palaeoniscids, crossopterygians and acanthodians, including *Megalichthys*, *Elonichthys*, *Strepsodus*, *Rhadinichthys*, and *Acrolepis*, have been found. The tubicolous annelid *Spirorbis pusillus* Martin occurs throughout the Band, being attached to both mussels and plant remains at different levels. The plants are represented by lycopods and *Calamites* in the black shale at the base, and allochthonous fragments of *Calamites*, *Cordaites*, and rare pteridosperms in the siltstone at the top of the Band.

TABLE 1. *Faunal phases of the Hopkins Band*

Hopkins Divisions (1927)	Faunal phases	Lithology
	6 Scattered <i>Naiadites</i> and plant fragments with attached <i>Spirorbis</i>	Siltstone and siliceous mudstone
	5 <i>Anthracosia</i> common, <i>Naiadites</i> without attached <i>Spirorbis</i> , <i>Carbonita pungens</i> and <i>C. humilis</i> rare	Siliceous mudstone and pale grey mudstone with ironstone
(3)	4 <i>Carbonicola</i> common, <i>Anthracosia</i> and <i>Anthraconaia</i> rare, <i>Naiadites</i> and <i>Spirorbis</i> common, <i>Carbonita pungens</i> and <i>C. humilis</i> common, <i>Geisina</i> rare.	Dark grey shale and mudstone with mussels.
(2)	3 <i>Geisina</i> , <i>Spirorbis</i> and fragmented <i>Naiadites</i> abundant	' <i>Geisina</i> Phase'; Black shale laminae
	2 <i>Geisina</i> common, <i>Naiadites</i> and <i>Spirorbis</i> scattered, <i>Carbonita pungens</i> common	Black carbonaceous shale
(1)	1 <i>Carbonita pungens</i> common, fish scales and plants	Black shale and mudstone conglomerate

Faunal phases. By detailed analysis of the relative density of the various fossils on bedding planes throughout the vertical thickness of the Hopkins Band at twelve localities, it has been possible to recognize a vertical sequence of six faunal phases. Text-fig. 3 shows the faunal distribution and faunal phases at the type-locality of the Band. Each of these phases, numbered 1 to 6, is characterized by changes in the dominance of the fossils present, as represented in Table 1.

The ostracod *Geisina arcuata* has so far only been found in phases 2, 3, and 4 and only occurs in real abundance in the *Geisina* Phase, i.e. phase 3. In these phases *G. arcuata* is associated with *Naiadites*, *Spirorbis*, *Carbonita* and plant fragments, but rarely occurs with *Carbonicola*, and has never been found with *Anthracosia* (text-fig. 3). The species *Carbonita pungens* and *C. humilis* have a longer vertical range than *Geisina arcuata*, occurring from phase 1 to phase 5, and are thus associated at different levels with all elements of the fauna.

A similar sequence of faunal phases was described by Eagar (1961) from the shales

above the Flockton Thin and Flockton Thick Coals near Wakefield in Yorkshire (Table 2).

Although *Geisina* is listed in three of Eagar's phases, he did not record the presence of associated species of *Carbonita*. Dr. Eagar has kindly permitted me to examine his material and as in the Hopkins Band, *Carbonita humilis* and *C. pungens* occur throughout the sequence. In the Flockton succession, *Geisina arcuata* is again restricted to the more carbonaceous shale, but in phase 2 occurs in association with abundant specimens of *Anthraconaia*, a situation not paralleled in the Hopkins Band. The association of

TABLE 2. Faunal phases of Flockton Shales, Lower A. modiolaris Zone, L. Coal Measures, Cold Bath Opencast Site, Sheffield, Yorks. (from Eagar 1961)

Fauna	Lithology
5 <i>Naiadites</i> only, relatively sparse	Pale grey mudstone
4 <i>Anthracosia</i> abundant. Relatively high H/L ratio. <i>Naiadites</i> , <i>Anthraconaia</i> occasional	Grey, typically ferruginous mudstone with little carbonaceous matter.
3 <i>Carbonicola</i> abundant. Relatively low H/L ratio. <i>Naiadites</i> , <i>Anthraconaia</i> occasional. <i>Geisina</i> (<i>Jonesina</i>) very abundant	Dark fine grained richly carbonaceous shale marked by prolific quantities of ostracods, mainly of <i>Geisina</i> group.
2 <i>Anthraconaia</i> abundant with less common <i>Naiadites</i> . <i>Geisina</i> (<i>Jonesina</i>) very abundant	Macroscopic pyrite may occur, notably towards the base
1 <i>Naiadites</i> and <i>Geisina</i> (<i>Jonesina</i>) very abundant	
0 Fish scales abundant	

abundant specimens of *Carbonicola* and rare *Anthraconaia*, with *G. arcuata* in Eagar's phase 3, has a parallel in the lower part of phase 4 of the Hopkins Band in some localities, where *Geisina* persists a little above the *Geisina* Phase. As in the Hopkins Band *Geisina* is not known to occur with *Anthracosia*. Therefore, in both the Hopkins Band and the Flockton shales *Geisina* and *Carbonita* show distinct, but consistent, differences of range, population density, and faunal association.

DISTRIBUTION AND PALAEOECOLOGY OF THE OSTRACOD FAUNA

Vertical distribution. In order to study the vertical distribution of the ostracod fauna of the Hopkins Band, ostracods were extracted from two series of shale samples obtained throughout the vertical thickness of the Band at Bearpark Colliery, Co. Durham. The heights of the samples above the Harvey Seam and numbers of the various ostracods extracted are shown in Table 3.

There is a distinct vertical change in the species of ostracods present in the Hopkins Band, and this is independent evidence for the validity of the faunal phases outlined in the previous section of this paper. *Geisina arcuata* is restricted vertically, as previously mentioned, and only occurs abundantly in the *Geisina* Phase, where it is the dominant species. *Carbonita humilis* occurs throughout the vertical sequence, with fairly constant population density. The small 'darwinuloid' form *C. pungens* is most abundant in the

three inches of conglomerate and shale immediately above the coal, but it persists vertically, as shown in text-fig. 3. At higher levels, however, it cannot be extracted by the hydrogen-peroxide sludge technique that was used, because the fragile disarticulated valves are easily destroyed. A most interesting antipathetic relationship between the species *Carbonita evelinae* and *C. claripunctata* is suggested by this study (see Table 3). *Carbonita evelinae* is restricted to the grey shaly mudstone above the *Geisina* Phase ($3\frac{3}{4}$ – $4\frac{1}{2}$ in.), while *C. claripunctata* is absent from this mudstone, but is present in the *Geisina* Phase and in the black shale below.

TABLE 3. *Vertical distribution of ostracods in the Hopkins Band, Lower A. modiolaris Zone, L. Coal Measures, at Bearpark Colliery, County Durham*

Numbers indicate the number of specimens extracted

Height above Harvey Seam (in inches)	Species of ostracods				
	<i>Geisina arcuata</i>	<i>Carbonita humilis</i>	<i>Carbonita evelinae</i>	<i>Carbonita pungens</i>	<i>Carbonita claripunctata</i>
12–14		2	1		
$9\frac{1}{2}$ –10					
$8\frac{1}{4}$ – $9\frac{1}{2}$		4			
$7\frac{1}{2}$ – $8\frac{1}{4}$		31	25		
$6\frac{3}{4}$ – $7\frac{1}{2}$		12	3		
6– $6\frac{3}{4}$		35	6		
$4\frac{1}{2}$ – $5\frac{1}{2}$	9	36	14		
$3\frac{3}{4}$ – $4\frac{1}{2}$ (<i>Geisina</i> Phase)	101	38		1	4
2–3		6			
1–2		29		12	2
0–1		6		25	2
Total number of ostracods extracted	110	199	49	38	8

In the grey mudstone between $7\frac{1}{2}$ and $8\frac{1}{4}$ in. above the Harvey Seam, *C. evelinae* shows an increase in abundance in both series of samples, and rivals *C. humilis* as being the dominant member of the ostracod population (Table 3). A petrographic study of the enclosing mudstone shows a reduction in the amount of the coarser detrital constituents and the first appearance of framboidal pyrite, suggesting a decrease in the rate of sedimentation. Such a change in the rate of sedimentation could account for the relative abundance of ostracods at this level.

By measuring the height and length of the ostracod carapaces extracted from the series of samples at Bearpark, the number of moult stages or instars of the various species present at different levels was obtained. The lowest two inches of the black shale contain at least two moults of *Carbonita pungens* and *C. humilis* respectively, and three or more of *C. claripunctata*. In the *Geisina* Phase, all the ostracods extracted were adults. The mudstone above the *Geisina* Phase contains persistently two moults of *C. humilis*, while *C. evelinae* is present generally as the adult and rarely as the preceding instar as well.

The absence of early moults from the *Geisina* Phase was confirmed from all localities studied, not only Bearpark (e.g. the size-frequency distribution of *G. arcuata* at Eppleton, text-fig. 5), and could be due to removal by current sorting, or preservation, or

extraction failure. Petrographic examination of the *Geisina* Phase sediments shows that at some levels complete and fragmented ostracod carapaces are restricted to lenticular pockets or laminae within the sediments. This observation, when considered with their low clay mineral and high silt content, suggests that these sediments may have undergone mild winnowing by currents at the time of deposition. A thin band of carbonaceous shale with ostracods, very similar to the *Geisina* Phase, occurs above the Eighteen Inch Seam in the *A. modiolaris* Zone of the Cumberland Coalfield (Taylor and Calver 1961, p. 9). At least the three largest moults of both *Geisina arcuata* and *Carbonita humilis* are randomly distributed throughout the two inches of shale of this band. This shale is poorer in detrital silt, and richer in clay mineral material, than the *Geisina* Phase sediments, and probably accumulated more slowly under less turbulent conditions of sedimentation. This comparison further supports the suggestion that selective removal, or fragmentation, of the early instars by mild current action, rather than preservation failure, accounts for the absence of the young ostracod instars from the *Geisina* Phase of the Hopkins Band.

Lateral variation in the Geisina Phase. Samples of the *Geisina* Phase were examined in detail from eleven localities in the coalfield, besides Bearpark, to determine if any lateral changes in the ostracod fauna occurred (Table 4). No major lateral changes were found, apart from the rare occurrence of *Carbonita inflata* at two localities near Sunderland.

TABLE 4. *Ostracods extracted from the Geisina Band of the Hopkins Band at various localities in County Durham*

Numbers in parentheses refer to localities in text-fig. 2, numbers without parentheses indicate the number of specimens extracted

Localities	Ostracods extracted						Total
	<i>Geisina arcuata</i>	<i>Carbonita humilis</i> Male	<i>Carbonita humilis</i> Female	<i>C. claripunctata</i>	<i>C. evelinae</i>	<i>C. inflata</i>	
Follonsby (4)	99	3	2	2			106
Pelton (5)	177	36	62	2	6		283
Bearpark (6)	57	15	23	6	2		103
Whitworth (7)	24	5	13	1	6		49
Ferryhill (8)	97	6	7				110
Washington (12)	65	4	7	3	1		80
Hylton (13)	24	5	18	1	3	7	58
Silksworth (14)	122	77	79	3	4		285
Ryhope (15)	120	18	23	4	1		166
Durham Main (18)	34	1	9	1	1		46
Eppleton (19)	212	34	111	11	1	5	374
Bowburn (20)	32	6	12	1			51
<i>Total</i>	1063	210	366	35	25	12	1711
Approximate % of fauna	60	35		3			98

When all the 1711 ostracods extracted from the twelve localities are considered together the approximate proportions of species present in the *Geisina* Phase can be deduced. Approximately 60% of the ostracods are referable to *Geisina arcuata*, about

35% to *Carbonita humilis*, about 3% to *C. evelinae* and *C. claripunctata* together, and about 2% to *C. pungens*. *Carbonita inflata* is very rare and only of local occurrence.

As shown in Table 4, sexual dimorphism in *Carbonita humilis* was recognized at most localities, although the ratios of the dimorphs extracted varied considerably. Dimorphism was not recognized in any other species of *Carbonita*. The greatest population densities of ostracods in the *Geisina* Phase were found in the centre of the coalfield, at the localities Pelton, Follonsby, Eppleton, Silksworth, and Ryhope, where the Phase is between 1 and 1½ in. in thickness. In the localities towards the south and south-western part of the coalfield, at Durham Main, Bowburn, Ferryhill, and Whitworth Opencast Site, the shales of the *Geisina* Phase thin to between ¼ and ½ in. with an associated reduction in the population density of the ostracod fauna.

Palaeoecology of Geisina and Carbonita. The vertical changes in the ostracod fauna of the Hopkins Band are believed to be related to changing conditions in the environment of deposition of the sediments. In these sediments *Geisina arcuata* is associated with *Naiadites*, *Spirorbis*, *Carbonita*, and plant fragments, and is restricted to the carbonaceous shale with between 2% and 8% organic carbon. These facts suggest that in its ecology this ostracod was associated with plant matter, and a pseudoplanktonic fauna. Eagar (1961) and Heath (1961) reached similar conclusions regarding the ecology of this species. The genus *Carbonita*, however, does not show any particular vertical restriction or geochemical correlation and occurs with both pseudoplanktonic and benthonic faunas. These facts and the similarity of shell shape may indicate that in its ecology this genus is similar to the living *Cypridopsis* (Scott and Summerson 1943; Kesling 1951).

Several workers have suggested distinct palaeosalinity differences between these two genera. Jones, Kirby, and Young (1899), Scott and Summerson (1943), and Scott (1944), all suggested that *Carbonita* flourished mainly in freshwater lakes or lagoons. In the Ruhr Coal Measures, however, *Geisina* is considered to occur only in brackish or marine shales (Kremp and Grebe 1955; Ernst, Krejci-Graf, and Werner 1958; Ernst, Michelau, and Tasch 1960; Knauf 1963; and Böger 1964). The gradual predominance and final survival of *Carbonita* over *Geisina* in ostracod bands from the Lower to the Upper Coal Measures is thought by Calver (1966) to be due to the gradual reduction of marine influence on the Coal Measure environments.

The solution of the apparent enigma of these two genera occurring together is probably that salinity was not the sole ecological factor determining their distribution. Such related factors as types of bottom substrate, available food supply, and depth, may have been equally important.

In terms of detailed palaeoecology, *Geisina arcuata* appears to have been a browser on floating or deposited plant matter and to have had a wide salinity tolerance, perhaps being euryhaline. Some species of *Carbonita*, namely *C. humilis* and *C. pungens*, may have been ubiquitous bottom crawlers or near bottom swimmers (cf. *Cypridopsis*, Kesling 1951), while others show distinct substrate preferences, *C. claripunctata* to a carbon rich substrate and *C. evelinae* to a carbon poor substrate. *Carbonita* appears to have been oligohaline, tolerant of fresh to slightly brackish water, as it has not so far been found associated with what are normally regarded as marine faunas in the Coal Measures.

Palaeoecology and vertical distribution of the ostracods. This section is an attempt to reconstruct the changing conditions of the depositional environment from a consideration of changes in the sediments and associated faunas.

After the initial inundation of the swamp that later formed the Harvey-Beaumont Seam, quiet lagoonal conditions were presumably established over the area of the coal-field now occupied by the Hopkins Band (text-fig. 2). The sediment coming into this lagoon contained large and small plant fragments, together with silt and fine clay, which, after deposition, were compacted to form a carbonaceous shale with between 5% and 8% of organic carbon and up to 10% free silica. Such a lagoonal environment would have had a richly carbonaceous floor thickly populated by swarms of *Carbonita pungens*, scattered *C. humilis* and *C. claripunctata*, and small groups of *Geisina arcuata* clustered around decaying plant fragments.

Petrographic and geochemical examination of the sediments of the *Geisina* Phase shows these to be poor in detrital silt and fine clay, but are largely composed of organic carbon, pyrite, and calcareous shell material. This widespread Phase seems to represent a coquina of *Geisina*, *Carbonita*, *Naiadites*, *Spirorbis*, and plant matter, which accumulated under conditions of reduced inorganic detrital sedimentation, but mild turbulence.

The abrupt change in lithology at the top of the *Geisina* Phase suggests a change in the source and type of sediment being supplied to the environment. The faintly laminated shaly-mudstone that succeeds the *Geisina* Phase consists largely of clay minerals, less than 1% organic carbon, and less than 5% free silica. On this muddy substrate, a benthonic fauna of the lamellibranchs *Carbonicola* and *Anthracosia* and the ostracod *Carbonita* flourished. *Geisina arcuata* died out with the failure of the detrital plant matter, but a new species of *Carbonita*, *C. evelinae*, appeared and soon rivalled *C. humilis* as the dominant ostracod.

At a higher level in the mudstone there is a gradual increase in the detrital silt content, and the mudstone passes into a siltstone. This increase in silt in the water was probably the major factor responsible for the elimination of the Hopkins Band fauna. The benthonic lamellibranchs *Carbonicola* and *Anthracosia* first became scattered or grouped (Broadhurst 1964) and then disappeared, to be survived only by *Naiadites*, which probably had a pseudoplanktonic mode of life. *Carbonita* disappeared with the benthonic lamellibranchs.

The environment of deposition of the sediments and fossils of the Hopkins Band, described above, represents the basal lagoonal phase of a typical Coal Measure cyclothem. These fossiliferous sediments are nowhere more than 6 ft. thick and are succeeded by 40–50 ft. of deltaic sandstone that forms the main 'regression phase' (Payton and Thomas 1959) of the cyclothem. The ecological changes suggested above are those normal in such a lagoonal environment undergoing gradual sedimentary infilling with the approach of the deltaic phase of the cyclothem.

Acknowledgements. I would like to thank Dr. W. Hopkins for help and encouragement during the course of this work, Dr. F. W. Anderson for advice on ostracod taxonomy, Dr. F. M. Broadhurst and Dr. J. W. Stanley for offering many helpful suggestions, and Professor K. C. Dunham and his technical staff for the use of the facilities of the Department of Geology, University of Durham. I am grateful to the officers of the National Coal Board, Northumberland and Durham Divisions, for giving access to underground and opencast workings and borehole records; the Assistant Director and Mr. M. A. Calver of the Geological Survey Office, Leeds, for giving access to material in their collections; and to the Assistant Keeper and Dr. R. H. Bate of the British Museum (Natural History),

Dr. W. I. Rolfe of the Hunterian Museum, Glasgow, and Dr. R. M. C. Eagar of the Manchester Museum, for the loan of ostracod material. The work was carried out during the tenure of a D.S.I.R. Research Studentship, which is gratefully acknowledged.

SYSTEMATIC DESCRIPTIONS

As well as the new ostracod species proposed in this study, the other species recorded are briefly redescribed, since this is the first study involving large numbers of these ostracods from the British Coal Measures. The lectotype of *Geisina arcuata* is in the collections of the British Museum (Natural History) and is described here. The species of *Carbonita* are compared with lectotype material in the British Museum as designated by F. W. Anderson in a postscript to this paper. All numbers of specimens quoted are British Museum (Natural History) registration numbers.

Subclass OSTRACODA Latreille 1806
Order PALAEOCOPIDA Henningsmoen 1953
Suborder KLOEDENELLOCOPINA Scott 1961
Superfamily KLOEDENELLACEAE Ulrich and Bassler 1908
Family GEISINIDAE Sohn 1961
Genus GEISINA Johnson 1936
Geisina arcuata (Bean) 1836

Text-fig. 4 *a-f*

- 1836 *Cypris arcuata* Bean, p. 377, fig. 55.
1886b *Beyrichia arcuata* (Bean); Jones and Kirkby, p. 438, pl. 12, figs. 12-14.
non 1889 *Beyrichia arcuata* (Bean); Jones, p. 381, pl. 17, fig. 7*a-c*.
1908 *Jonesina arcuata* (Bean); Ulrich and Bassler, p. 324, pl. 44, figs. 17-19.
non 1927 *Jonesina arcuata* (Bean); Harlton, p. 205, pl. 32, fig. 6*a-c*.
1928 *Jonesina arcuata* (Bean); Knight, pp. 243-6, pl. 31, fig. 6*a-c*; pl. 33, fig. 6.
1932 *Sansabella arcuata* (Bean); Latham, p. 366, fig. 12.
1943 *Jonesina arcuata* (Bean); Scott and Summerson, p. 672, pl. 1, figs. 12-15, 19, 21.
1946 *Geisina arcuata* (Bean); Cooper, p. 110, name only.
1949 *Linnoprimitia arcuata* (Bean); Kummerow, p. 49, fig. 1.
1952 *Jonesina arcuata* (Bean); Marple, p. 936, pl. 135, figs. 4-8.
1953 *Linnoprimitia arcuata* (Bean); Kummerow, p. 15, pl. 1, fig. 7.
1955 *Jonesina arcuata arcuata* (Bean); Kremp and Grebe, pp. 159-62, pl. 1, figs. 8-10.
1957 *Jonesina arcuata* (Bean); Vangerow, p. 468, pl. 20, figs. 27-30.

Type specimens. Lectotype, In 43596, specimen 12; complete carapace, adult female, designated here. Paratype, In 43596, specimens 1-7, 10, 18-23 (Ex Bean Collection, purchased Kirkby 1888).

Dimensions. Lectotype: length, 1.28 mm.; height, 0.81 mm.; width, 0.62 mm.

Type locality. Newcastle area (see discussion).

Type horizon. Coal Measures, probably Hopkins Band, Lower *A. modiolaris* Zone, Lower Coal Measures (see discussion).

Description. Carapace sub-ovate to sub-rectangular in lateral view. Dorsal margin straight, hinge line slightly depressed in posterior half; ventral margin convex. Ends rounded, the anterior more than the posterior. Anterior cardinal angle obtuse, posterior

cardinal angle 90° or less. Greatest height median; greatest width median in the male, posterior of middle in the female, giving a strongly sub-ovate dorsal outline.

Anterior sulcus S1 weak, wide, and shallow, or absent. Posterior to S1 there is an indistinct node that fades towards the dorsum. Median sulcus S2 prominent, slightly anterior of middle, extending from dorsal margin to central area, straight sided, deepest and widest in the dorso-central area. Posterior to S2, the shell swells dorsally above the hinge line in a raised area.

Right valve the larger, overlapping the left at the ventral and end margins. On the exterior of the right valve are two swellings, one on the central anterior border and the other at the posterior cardinal angle. Anterior swelling is a low pointed bulb which imparts pointed appearance to the anterior end of the right valve. Posterior swelling is a rectangular bulb which curls posteriorly and gives the distinctly right-angled appearance to the postero-dorsal corner. Ventral edge of the right valve is thickened and projects below the left valve on overlap. Left valve smaller, lacks the swellings of the right, but is distinctly rimmed.

Hinge line straight, about two-thirds length of dorsal margin, with flexure of right valve over the left at both cardinal angles. Surface ornament a reticulate pattern of polygonal pits over the lateral surface of both valves.

Internal features. The internal features could not be seen on the articulated carapace of the lectotype, so they are described from both complete and fragmentary valves of this species from the Hopkins Band of Durham and the Flockton Shales of Yorkshire.

Hinge structure is of true *Geisina* type (Johnson 1936, p. 22). There is a narrow shallow groove in the dorsal contact margin of the right valve into which the dorsal edge of the left valve fits. In the anterior half of the hinge of the right valve the groove is wide, and its lower edge is reflexed ventrally into a sloping flange, so that the anterior half of the hinge of the left valve is reflexed upwards to overlap the flange of the right valve, as described by Johnson (text-fig. 4e).

A wide thickened rim runs internally around the contact margin of both valves. This rim may be the remains of the duplicature, stated by Sohn (1961, p. 182) to be present in this genus. In the thickened rim of the right valve there is a ridge and groove to accommodate the overlapped edge of the left valve.

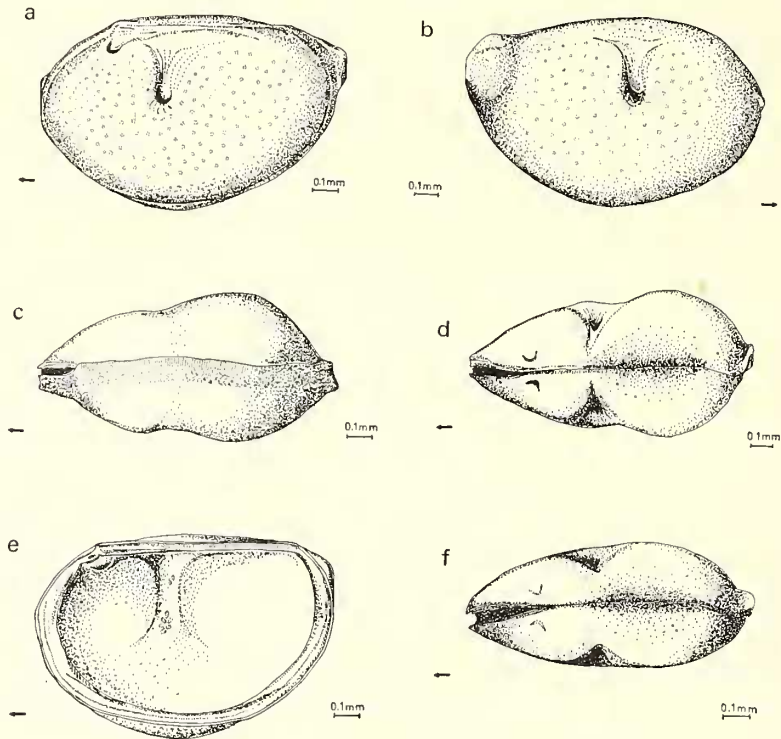
The median sulcus S2 swells and thickens slightly internally to form a ridge that fades in the central area. Rarely, faint markings suggesting two groups of muscle scars can be seen on this ridge.

Other features from a study of specimens from the Geisina Phase. Dimorphism can be clearly recognized in any population of this ostracod. It is of typical kloedenellid type (Scott and Wainwright 1961), being shown by the inflation of the posterior part of the carapace of the female, giving distinctly different dorsal outlines to the dimorphs (text-fig. 4d, f). Johnson (1936) describes differences in lateral shape as well as posterior inflation between the dimorphs of the type species *Geisina gregaria*, but no such differences are discernible in *G. arcuata*.

In a sample of 180 well-preserved specimens of this species from Eppleton, near Sunderland, 80% fall within a range of size dimensions: length, 1.10–1.30 mm.; height, 0.60–0.80 mm. The mean sizes are: length, 1.17 mm.; height, 0.72 mm., slightly smaller than the lectotype. When this range of size dimensions is plotted graphically

(text-fig. 5), it confirms that only one instar is present. The dimensions given by other workers for synonymous or allied species of *G. arcuata* are plotted in text-fig. 5 and suggest that in many cases they are earlier moults than those represented in the *Geisina* Phase.

Discussion. Morphologically this species is fairly close to the American type species *G. gregaria*, and although lacking its postero-dorsal spine, has a rectangular bulb in a

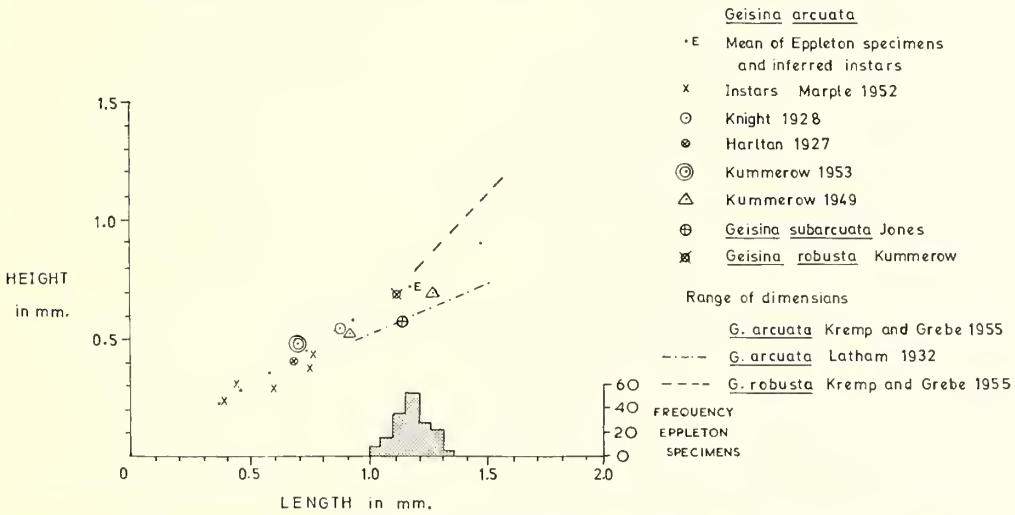


TEXT-FIG. 4. *Geisina arcuata* (Bean). *a-d*, Lectotype, In 43596, specimen 12. *a*, exterior view of left valve; *b*, exterior view of right valve; *c*, ventral view of entire carapace; *d*, dorsal view of entire carapace showing posterior inflation of the female; *e*, interior of the right valve showing grooved hinge and thickened marginal rim, specimen from Flockton Shale of Yorkshire; *f*, dorsal view of complete male carapace from Hopkins Band at Eppleton Colliery, County Durham.

similar position. *G. arcuata* is distinguished from *G. subarcuata* Jones, the only other species of this genus recorded from the British Coal Measures, by the smaller size of the adult, the deeper median sulcus S2, and the presence of the exterior bulbs on the right valve. In many characters this species closely approaches various of the American species of *Geisina* listed by Echolls and Creath (1959), previously described by other workers.

Because of the confused taxonomic history of this species, as revealed by the synonymy, it is necessary to discuss the choice of type material and the generic relationships. The original description by Bean (1836) was brief and in general terms, and the original figure very poor. The type locality and horizon were likewise vague, being 'the coal

formation near Newcastle'. The specimen proposed here as the lectotype, however, from the British Museum collection, bears the label '*Cypris arcuata* mihi' in Bean's handwriting. This proposed lectotype comes from a piece of shale lithologically and faunally identical with the *Geisina* Phase of the Hopkins Band in the Newcastle area. The historical record (*History of Northumberland*, 1930, 8, p. 25) shows that the Beaumont Seam was being worked about 1836 along the north bank of the Tyne west of Newcastle, and so it is here suggested that a fragment of the roof shale of this seam, rich in *G. arcuata*, was sent by an interested amateur, 'Mr. Alder' (Bean 1836, p. 377), to the well-known Yorkshire naturalist, William Bean. Therefore, it is believed that the



TEXT-FIG. 5. Height and length dimensions of *Geisina arcuata* (Bean) and related species.

specimens of this species described in this paper come from the type horizon and approximately the type locality of *G. arcuata* (Bean).

Jones and Kirkby (1886b) gave the first detailed description of this species as *Beyrichia arcuata* (Bean), and recorded its occurrence from the Coal Measures of the Midlands, Manchester, Lanark, and County Durham (Ryhope and Claxheugh). Material from these localities is preserved in the Kirkby Collection in the British Museum (Natural History), and apart from the Lanarkshire specimens, from Carluke, they appear to be *G. subarcuata*, as their localities in the Middle Coal Measures would suggest. The species was placed in the genus *Jonesina* by Ulrich and Bassler (1908) when they erected this genus on the type species *Beyrichia fastigiata* Jones and Kirkby without description of, or reference to, a type specimen. However, when Johnson (1936) erected the new genus *Geisina* for a Nebraskan Pennsylvanian form, he borrowed the only known material of '*Beyrichia*' *fastigiata* identified by Jones and Kirkby, in the British Museum collections, and distinguished between *Geisina* and *Jonesina*. Although Johnson (1936) described only one species, *Geisina gregaria* (Ulrich and Bassler), *Jonesina arcuata* was referred here by Cooper (1946), but only as a passing mention without examination of any material.

The specimens *Jonesina* 'Beyrichia' *fastigiata* in the British Museum (numbered I 1774 and In 32494-6) have been re-examined and compared with *G. arcuata*. The genus *Jonesina* is considered to be valid and cannot be dismissed as suggested by Sohn (1961, p. 413), and differs from *Geisina* in the valves being strongly and deeply bisulcate, the median sulcus S2 being deep and terminating in a pit, the hinge not being depressed in the posterior half, and the hinge structure only showing overlap at the cardinal angles. These characters correspond to those given as distinctive of *Jonesina* in an apparently little-known revision of the generic diagnosis by Cooper (1941, pp. 55, 56).

Post-war German work on Ruhr Coal Measure ostracods has shown an ignorance of both American literature and the existence of type material of *G. arcuata* in British collections. Kummerow (1949, 1953) proposed and described a new genus, *Limnoprimitia*, for *G. arcuata*, but Kremp and Grebe (1955, p. 161) dismissed the genus as invalid because of the poor state of preservation of the original material. On the advice of Dr. B. Kellett, however, Kremp and Grebe (loc. cit.) considered both *Limnoprimitia* and *Geisina* to be synonymous with *Jonesina* and so have retained the species as *Jonesina arcuata*. Their further subdivision of the species into *J. arcuata arcuata* and *J. arcuata cingulata* seems to be due to their confusion of the latter variety with the species *Geisina subarcuata* (Jones).

Stratigraphical distribution. Published records of *G. arcuata* in Britain range from the Lower Carboniferous to the Upper Coal Measures, but most probably this species is really restricted to the Lower Coal Measures. The Scottish Lower Carboniferous forms may well belong to *Sansabella*, *Jonesina*, or other Mississippian genera, while the higher Coal Measure forms are generally close to *G. subarcuata*. Authors such as Wright (1931), and Edwards and Stubblefield (1947) are probably correct in referring the range of the species to the *C. communis* and Lower *A. modiolaris* Zones of the Coal Measures, that is, to horizons below the Clay Cross Marine Band.

A similar stratigraphical range for this species exists in the European coalfields. Pruvost (1930) stated that it is an excellent zonal indicator of Westphalian A, while Kremp and Grebe (1955) recorded it as occurring in Namurian C and Westphalian A, but not above the Katharina (= Clay Cross) Marine Band.

Echolls and Creath (1959) recorded that the range of *G. arcuata* in the United States is Lower and Middle Pennsylvanian, from the Morrowan to the Desmoinesian stages. This is broadly equivalent to the European Westphalian. However, Scott and Summerson (1943) described 'Jonesina' *arcuata* occurring in abundance with species of *Carbonita* and *Anthraconaia modiolaris* in the Hance Formation of Tennessee. They correlated this horizon with the Upper Westphalian A stage of the European Coal Measures.

The general picture therefore seems to suggest that despite its wide distribution from central and eastern United States, and across Europe as far as the Russian coalfields, *Geisina arcuata* (Bean) has a limited stratigraphical range, from Namurian C to the top of Westphalian A. It is at its greatest abundance in Upper Westphalian A, which is equivalent to the Lower *A. modiolaris* Zone of the British Coal Measures in which the ostracod fauna from the Hopkins Band of County Durham occurs.

Order PODOCOPIDA Müller 1894
 Suborder PODOCOPINA Sars 1866
 Superfamily CYPRIDACEA Baird 1845
 Family CYPRIDIDAE Baird 1845

(Placed here by Cooper 1946, family uncertain Swain 1961)

Genus CARBONITA [CARBONIA] Jones 1870

(Preoccupied by *Carbonia* Robineau-Desvoidy 1863 = *Carbonita* Strand (1926; 1928, pp. 40, 41)

Type species. *Carbonita* [*Carbonia*] *agnes* Jones 1870.

Generic diagnosis. Carapace sub-ovate, ovate-oblong, or elongate. Greatest height usually in the posterior third; greatest thickness median to posterior. Dorsal margin slightly to broadly convex; ventral margin straight to slightly convex. Ends unequal, broadly rounded to acutely pointed. Hinge in the middle third of the dorsal margin, straight and simple with the left valve usually raised above the right along the hinge line, closely adpressed or with a narrow groove. Right valve the larger, overlapping the left on the ventral margin and narrowly overlapping or over-reaching left on the end margins. Surface smooth to coarsely reticulate. Ornament may consist of longitudinal striae or concentric reticulation, but may vary with preservation. Muscle scar circular, sunk into the shell, anterior or antero-ventral of the mid-point. Major muscle scar encloses a variable pattern of secondary scars. Shell usually thickened internally postero-ventrally of the muscle scar, in a low ridge that may leave a pronounced furrow on internal moulds.

Carbonita humilis (Jones and Kirkby) 1879

Text-fig. 6

- 1879 *Carbonia fabulina* var. *humilis* Jones and Kirkby, p. 31, pl. 2, figs. 11-14.
 1884 *Carbonia fabulina* var. *humilis* Jones and Kirkby, p. 388, pl. 2, fig. 9.
 1911 *Carbonia fabulina* (Jones and Kirkby) in part; Pruvost, pp. 68-70, pl. 2, figs. 1-8.
 1930 *Cytherella foveolata* Wright, p. 49, pl. 1, fig. 2a-b.
 Non 1955 *Carbonita humilis* (Jones and Kirkby); Kremp and Grebe, p. 151, pl. 16, fig. 1.
 1955 *Whipplella rhenana* (Kummerow); Kremp and Grebe, pp. 155-7, pl. 16, figs. 5, 6.
 1955 *Whipplella cenisa* Kremp and Grebe, pp. 152-5, pl. 16, figs. 3, 4.

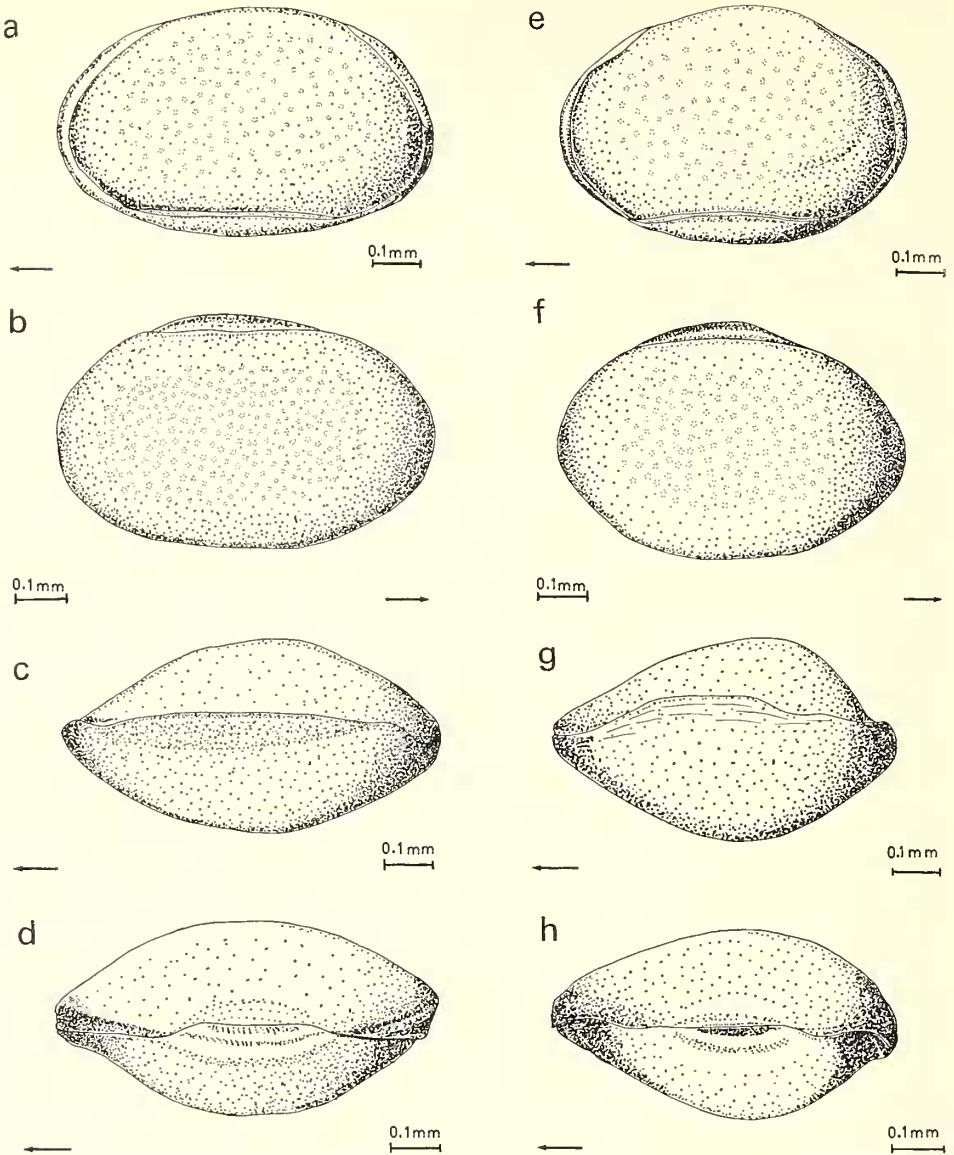
Lectotype. A figure; Jones and Kirkby 1879, pl. 2, fig. 14. Chosen by Anderson (see Postscript); type material not found.

Specimens described. Female, IO 2980, Hopkins Band, Bearpark Colliery, Co. Durham. Male, IO 2981, Hopkins Band, Ryhope Colliery, Co. Durham.

Dimensions. In mm.

		Length	Height	Width
Female	IO 2980	0.74	0.48	0.43
Male	IO 2981	0.81	0.48	0.41

Description. Female. Carapace tumid, sub-ovate, dorsal margin gently convex, ventral margin straight to slightly convex. Ends rounded, posterior more obtuse. Greatest height just posterior of the middle, while the greatest width is well posterior of middle. Ridge of thickening externally at antero-ventral corner of the left valve. Hinge short, straight, in central third of dorsal margin, left valve raised above the right along the hinge with a narrow groove between the valves. Valves unequal, right overlaps the left



TEXT-FIG. 6. *Carbonita humilis* (Jones and Kirkby). *a-d*, specimen IO 2981, complete male carapace. *e-h*, specimen IO 2980, complete female carapace. *a*, exterior left valve; *b*, exterior right valve; *c*, ventral view; *d*, dorsal view; *e*, exterior left valve; *f*, exterior right valve; *g*, ventral view; *h*, dorsal view.

on ventral and both end margins. Ventral overlap wide, end overlap narrow but distinct. Shell surface distinctly pitted with small polygonal pits. Internally valves are bordered with a narrow rim and they possess a typical muscle scar and slightly thickened ridge postero-ventral of the muscle scar.

Male. As female except lateral shape elongate-ovate, maximum height and thickness median, not posterior of middle. Height to length ratios: male about 60%, female 70%.

Discussion. In the original description of *Carbonia fabulina* var. *humilis* Jones and Kirkby (1879, p. 31) emphasized that this variety differed from *C. fabulina* (sensu stricto) in the flatter dorsal margin and the rounded ends being more nearly alike. These characteristics fit the male of the species as described above, and the original figures (pl. 2, figs. 11, 12) are of the male. The lectotype, however (pl. 2, fig. 14), is relatively higher than the others, sub-ovate with a blunter posterior, and although an internal mould it is probably a female. It thus seems that although only the male was originally described by Jones and Kirkby (1879), both forms were recognized and figured.

In the later description of *C. fabulina humilis* from the Nova Scotia Coal Measures, Jones and Kirkby (1884) stated that this form is further distinguished from *C. fabulina* (sensu stricto) by the thicker shell, the distinct pitting, and stronger amount of overlap. These differences appear to be persistent, so the 'var. *humilis*' of Jones and Kirkby has been elevated to specific rank by recent workers (Kremp and Grebe 1955; Copeland 1957; Anderson (in press). This present study of the population of *C. humilis* in the Hopkins Band confirms that it is a species in its own right.

Although Jones and Kirkby originally recorded *C. fabulina* var. *humilis* from both the Lower and Upper Carboniferous, this distinctly pitted form with strong marginal overlap seems typical of the Coal Measures, while *C. fabulina* (sensu stricto) may be restricted to the Lower Carboniferous. This stratigraphical distinction has been proposed by Dr. F. W. Anderson (pers. comm.), and so the lectotype figure he has chosen is from the Coal Measures at Pirnie Colliery, Fife.

Cytherella foveolata Wright, described and figured by Wright (1930) is undoubtedly *C. humilis* in an inverted orientation (cf. text-fig. 6 with Wright 1930, pl. 1, fig. 2a, b). This conclusion is confirmed by Dr. Anderson's examination of Wright's specimens, and material from this horizon in the collections of the Geology Department of Manchester University, examined by me.

The form described and figured by Kremp and Grebe (1955, p. 151, pl. 16, fig. 1) is not considered synonymous with *C. humilis* as described here. However, the forms they describe and figure as *Whipplella cenisa* and *W. rhenana* are probably the male and female dimorphs of *C. humilis* respectively. The lateral outlines, overlap, hinge, and dimension ratios are all similar to those of the respective dimorphs described here. The American genus *Whipplella* Holland 1934 was erected for forms like *C. fabulina* (sensu lato) but with a stronger marginal overlap. The overlap can be so variable in this form that *Whipplella* and *Carbonita* are here considered to be synonymous, in agreement with Cooper (1946, p. 67).

Stratigraphical distribution. The species *C. humilis* is common throughout the Coal Measures, although its acme is probably in the *A. modiolaris* Zone at about the horizon of the Hopkins Band. It is the dominant species of *Carbonita* in the Bottom Three Quarter Seam ostracod band in the *C. communis* Zone of Durham (text-fig. 1), and is abundant in the Upper *A. similis*-*A. pulchra* Zone faunas from both Ryhope Colliery, Durham, and the 'Foveolata Zone' of Wright (1931) from the Manchester area. There are frequent references to the occurrence of this form in the *A. phillipsi* Zone faunas of the Ardwick Series of Manchester (Jones and Kirkby 1890) and the Newcastle Beds of North Staffordshire (Melville 1946).

Carbonita evelinae (Jones) 1870

Text-fig. 7

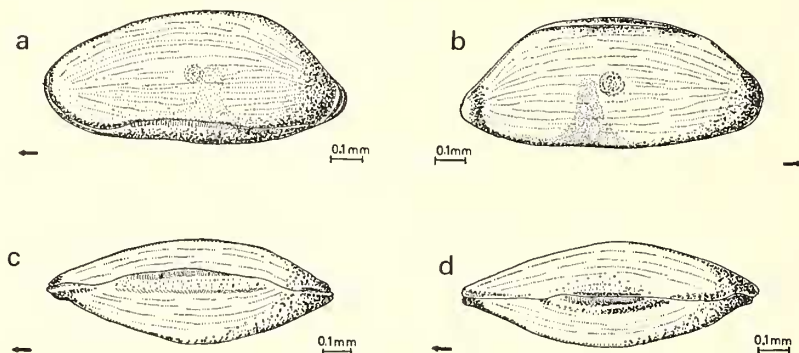
- 1870 *Carbonia evelinae* Jones, p. 218, pl. 9, fig. 4.
 1870 *Carbonia agnes* var. *rugulosa* Jones, p. 218, pl. 9, fig. 8.
 1870 *Carbonia agnes* var. *subrugulosa* Jones, p. 218, pl. 9, fig. 7.
 1866 *Carbonia wardiana* Jones and Kirkby, p. 265, pl. 9, fig. 10a, b.
 1943 *Hilboldtina evelinae* (Jones); Scott and Summerson, p. 870.
 1957 *Hilboldtina evelinae* (Jones); Copeland, p. 28, pl. 1, figs. 5-7.

Lectotype. In 56370, specimen 9; chosen by Anderson (see Postscript).

Specimen described. IO 2985, Hopkins Band, above *Geisina* Phase, Bearpark Colliery, Co. Durham.

Dimensions. Length, 0.94 mm.; height, 0.42 mm.; width, 0.30 mm.; H/L ratio, 44.7 %.

Description. Carapace elongate, sub-ovate. Dorsal margin slightly arched; ventral margin straight to slightly convex. Anterior end obtuse, lower than posterior; posterior



TEXT-FIG. 7. *Carbonita evelinae* (Jones). a-d, specimen IO 2985, complete carapace. a, exterior left valve; b, exterior right valve; c, ventral view; d, dorsal view.

end more acutely pointed, high and with a steep postero-dorsal slope. Greatest height median; greatest width posterior of middle giving an elongate-ovate dorsal outline. Hinge straight, less than half the length, left valve raised along hinge line but no groove between the valves.

Valves almost equal, right valve narrowly overreaches left on the free ends and overlaps it along ventral margin. Shell surface ornamented by fine longitudinal striae or ridges that converge towards the ends. These striae may be weakly developed or absent. Internally the shell has a circular muscle scar and ridge of thickening posterior to it. The muscle scar may contain a number of polygonal secondary scars.

Discussion. Dimorphism has not been detected in specimens of this species from the Hopkins Band.

The lectotype of *C. evelinae* in the British Museum (Natural History) is badly crushed, with strong longitudinal striae, a muscle spot, and pattern of cracks very close to those on Jones's original figure (Jones 1870, pl. 9, figs. 4a, b). Because of the crushed state of this specimen, I agree with Dr. F. W. Anderson (in press) that the shape distinction between *C. evelinae*, *C. agnes rugulosa*, and *C. agnes subrugulosa* drawn by Jones is not

valid. All these three forms are probably one species, *C. evelinae*, similar in shape to *C. agnes* but differing in the surface ornament. Likewise, the species *C. wardiana* Jones and Kirkby, of which type material is in the Kirkby Collection in the British Museum (I 1695), is considered synonymous with *C. evelinae*. The Hopkins Band specimens described here are a little closer in lateral outline to *C. wardiana* than to *C. evelinae* (sensu stricto) but the variable nature of this character does not warrant specific distinction.

The genus *Hilboldtina* Scott and Summerson 1943 was erected for elongate forms of *Carbonita* with striated surface ornament from the Pennsylvanian of North America. This genus is here considered synonymous with *Carbonita*, since surface ornament is not a character of generic value, and the other characters mentioned in the original diagnosis of *Hilboldtina* are present in most species of *Carbonita* as described here.

Stratigraphical distribution. The lectotype of this species is from the Upper Coal Measures, *phillipsi* Zone, of the South Wales Coalfield. The form *C. wardiana* was first recorded from a similar horizon in North Staffordshire. The presence of this species in the Hopkins Band in the *modiolaris* Zone of Co. Durham is the first published record of its occurrence outside the Upper Coal Measures, although similar specimens may be seen in the Geological Survey collections from the Upper *A. modiolaris* Zone of the Cumberland Coalfield.

It seems probable that although this species is predominantly an Upper Coal Measure form, it occurs rarely throughout the Coal Measures. Similar elongate striated specimens of *Carbonita* are reported by Scott and Summerson (1943) from the Pennsylvanian of Tennessee and by Copeland (1957) from the Upper Carboniferous of Nova Scotia.

Carbonita inflata (Jones and Kirkby) 1879

Text-fig. 8

- 1879 *Carbonia fabulina* var. *inflata* Jones and Kirkby, p. 31, pl. 2, figs. 15-99.
 1933 *Bythocypris tumidus* Upson, p. 24, pl. 2, fig. 11a-c.
 1934 *Whipplella cuneiformis* Holland, p. 344, pl. 25, fig. 5a-c.
 1935 *Carbonita? tumida* Kellett, p. 160, pl. 16, fig. 9a-c.
 1946 *Carbonita inflata* (Jones and Kirkby); Cooper, p. 66, pl. 8, figs. 40-42.
 1957 *Carbonita inflata* (Jones and Kirkby); Copeland, p. 26, pl. 1, figs. 12-14, pl. 2, figs. 18, 19.

Lectotype. I 1745; chosen by Anderson (see Postscript).

Specimen described. IO 2986, Hopkins Band, Hylton Colliery, Sunderland, Co. Durham.

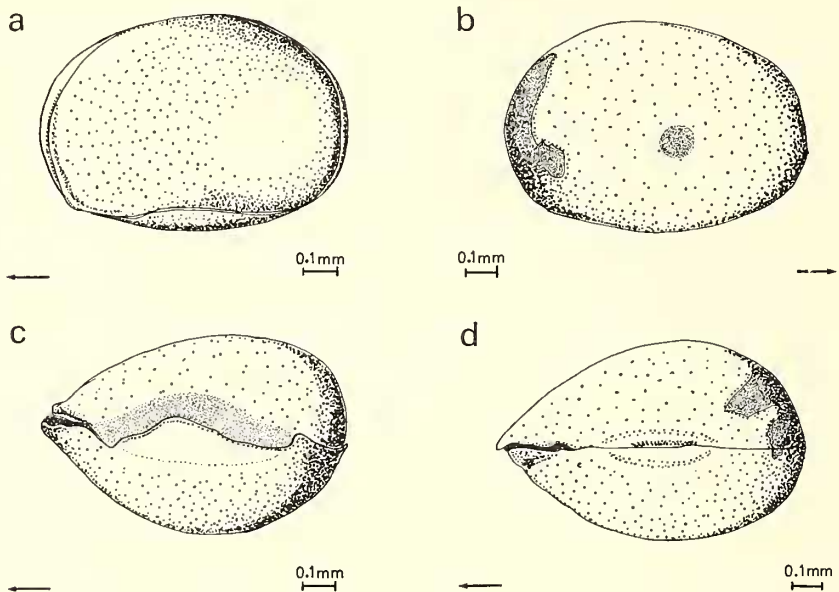
Dimensions. Length, 0.97 mm.; height, 0.68 mm.; width, 0.63 mm.; ratio H/L, 70%; width/height, 92.5%.

Description. Carapace tumid, sub-ovate. Dorsal margin convex; ventral margin straight to slightly concave. Ends rounded, anterior more obtuse than the posterior, which is distinctly tumid. Greatest height and width posterior and dimensions almost equal (W/H ratio: > 90%). Dorsal outline subcuneiform or broad sub-ovate.

Hinge short, in middle third of dorsal margin, depressed in a distinct but shallow groove. Left valve hardly raised above right along the hinge line. Valves unequal, right valve overlaps left around free margin. Overlap most pronounced on anterior margin

and anterior end of ventral margin. Ventral overlap narrow and ventral margin is flattened along area of overlap. Externally the left valve possesses a low thickened ridge antero-ventrally. Shell coarsely pitted, and is generally thick with rimmed margins internally. Muscle scar circular antero-ventral of mid-point.

Discussion. This species is rare in the Hopkins Band and was only found at two localities, Hylton and Eppleton. No details of moults or dimorphism are known. The specimens described are very similar to the original description and figures of Jones and Kirkby, and to the lectotype in the British Museum (Natural History). The coarsely pitted thick



TEXT-FIG. 8. *Carbonita inflata* (Jones and Kirkby). *a-d*, specimen IO 2986, complete carapace. *a*, exterior left valve; *b*, exterior right valve; *c*, ventral view; *d*, dorsal view.

shell, tumid carapace, with posterior width nearly equal to height, and short depressed hinge, are all sufficiently persistent characters to make the var. *inflata* of Jones and Kirkby a species in its own right.

Cooper (1946) examined the type material of the various species named by Upson, Holland, and Kellett, given in the synonymy, and considered them to be conspecific with *C. inflata* Jones and Kirkby. My redescription of this species and comparison with the descriptions and figures of the various authors, confirms this synonymy. Many of the characters by which these authors distinguished their species from *C. inflata* are in fact present on perfectly preserved specimens of the latter species but were not included in the original description. The synonymy of this form with *Whipplella cuneiformis* Holland, the type species of *Whipplella*, is an additional reason for the rejection of this genus as suggested in the discussion of *C. humilis*.

Stratigraphical distribution. The lectotype comes from the Coal Measures at Pirnie Colliery in Fifeshire, but the precise level within the Coal Measures is not recorded.

Forms similar to those described here from the *A. modiolaris* Zone are included in *C. fabulina* (sensu lato) recorded from the Upper *similis-pulchra* Zone of Durham, but they have not been found in the Three Quarter Seam Band in the *C. communis* Zone. *C. inflata* is also a common form in the *A. phillipsii* Zone faunas of North Staffordshire and the Manchester area. It seems probable that this species occurs sporadically throughout the Coal Measures.

Cooper (1946) recorded this species from the Pennsylvanian of Illinois, and the synonymous forms of other authors come from the Pennsylvanian of Nebraska, Kansas, Pennsylvania, and West Virginia. This species is also a common one in the Upper Carboniferous faunas of Nova Scotia described by Copeland (1957).

Carbonita pungens (Jones and Kirkby) 1879

- 1867 *Cythere pungens* Jones and Kirkby, p. 222.
 1879 *Carbonia pungens* Jones and Kirkby, p. 37, pl. 3, figs. 21–23.
 1884 *Cythere* (*Darwinella*) *pungens* (Jones and Kirkby); Jones, pp. 319, 325.
 1911 *Carbonia pungens* (Jones and Kirkby); Pruvost, pp. 71–72, pl. 12, figs. 13, 14.
 1932 *Carbonia pungens* (Jones and Kirkby); Latham, p. 386.
 1946 *Darwinula pungens* (Jones and Kirkby); Cooper, p. 78, pl. 10, figs. 39, 40.
 1957 *Carbonita pungens* (Jones and Kirkby); Copeland, p. 26.

Lectotype. I 1731, no. 6; chosen by Anderson (see Postscript).

Specimens described. IO 2987a–c, black shale below the *Geisina* Phase, Bearpark Colliery, Co. Durham.

Dimensions. In mm.

	<i>Length</i>	<i>Height</i>	<i>Width</i>	<i>H/L ratio</i>
IO 2897a	0.53	0.26	0.22	49.2 %
IO 2897b	0.44	0.19	0.18	43.2 %
IO 2897c	0.57	0.29	0.19	50.8 %

Description. Carapace small, sub-cylindrical in shape, ends equal. Dorsal margin straight or flatly convex, sloping from posterior to anterior; ventral margin straight. Anterior end low and pointed; posterior end high, rounded, and somewhat tumid. Greatest height and width posterior, the height being less than half the length ($H/L < 50\%$). Dorsal and ventral outlines sub-cuneiform, thickness about equal to height.

Hinge line straight, low, longer than half the length. Left valve not raised along hinge line and no groove. Valves almost equal, the right slightly larger and overlapping the left narrowly along the ventral margin. Maximum overlap in posterior half of ventral margin. Shell not preserved on Durham specimens; thin and smooth on type specimens. Muscle spot antero-ventral of mid-point, arrangement of secondary scars uncertain.

Discussion. Although the specimens described here are too badly preserved to be figured, their general features are close to the original description and figures of Jones and Kirkby (1879). These specimens are smaller than those of Jones and Kirkby but comparable with the dimensions given for this species by Latham (1932).

The generic relationship of this species has been in doubt since its earliest description, as the synonymy suggests. In 1884 Jones doubtfully referred it to *Darwinella* (= *Darwinula*, *Darwinella* preoccupied). Brady and Robertson, and several later authors, followed suit. Cooper (1946), describing American specimens he considered synonymous,

removed this species from *Carbonita* and placed it in *Darwinula* on account of its hinge structure and the character of the overlap of the valves. The left valve is not raised above the right along the hinge as in most species of *Carbonita*, but the variation of this character within the genus suggests that the simple hinge of *C. pungens* is more a matter of structural simplicity in this thin shelled form than a fundamental generic distinction. Cooper also suggested that in *C. pungens* the maximum overlap of the valves is around the ends, not along the ventral margin as is the normal situation in *Carbonita*. However, the lectotype specimen shows the normal *Carbonita* overlap, not that described by Cooper.

C. pungens is certainly darwinuloid in shape but the distinctive *Darwinula* pattern of muscle scar has not been recorded. It is considered, therefore, best to retain this species in the genus *Carbonita*.

The frequent occurrence of bedding planes in Coal Measures shale crowded with myriads of *C. pungens* is comparable to the mode of occurrence of *Darwinula* proper in Mesozoic, Tertiary, and Recent non-marine sediments (Jones 1885; Kaufmann 1900; Harper and Sutton 1935; and Swain 1955). Mandelstam (1956) also recorded a similar occurrence, with up to forty variants of *Darwinula*, from the Upper Permian rocks of the Kuznetsk Coalfield of Russia. In mode of occurrence, therefore, if not in structure, *C. pungens* is very like *Darwinula*.

Stratigraphical distribution. The lectotype of this species comes from one of Jones and Kirkby's original localities, the Coal Measures at Methil in Fifeshire, but the same authors also recorded this form from freshwater limestones in the Carboniferous Limestone Series of Scotland. In the English Coal Measures, Jones and Kirkby (1890) recorded its abundance in the Upper Coal Measures of the Manchester area. Edwards and Stubblefield (1947) found it in the Upper *similis-pulchra* Zone of Nottinghamshire and Derbyshire. The present study has shown the abundance of *C. pungens* in both the *A. modiolaris* and *C. communis* Zones of Durham (text-fig. 1). These records, though sparse, suggest that this species ranges throughout the Coal Measures in Britain and occurs locally in the Lower Carboniferous of the Central Valley of Scotland.

This species has also been recorded from the Coal Measures of France by Pruvost (1911), the Pennsylvanian of Illinois by Cooper (1946), and the Upper Carboniferous of Nova Scotia by Copeland (1957).

Carbonita claripunctata sp. nov.

Text-fig. 9

- 1879 *Carbonia raukiniiana* Jones and Kirkby, p. 34 (in part), pl. 3, figs. 3, 8.
 1897 *Carbonia rankiniiana* (Jones and Kirkby); Dawson, p. 396, fig. 10.
 1932 *Carbonia rankiniiana* (Jones and Kirkby); Latham, p. 385 (in part).
 1955 *Carbonita agnes* (Jones); Kremp and Grebe, p. 148, pl. 16, fig. 2.

Derivation of name. *Clarus* (lat.)—distinct; *punctatus* (lat.)—pitted, punctate.

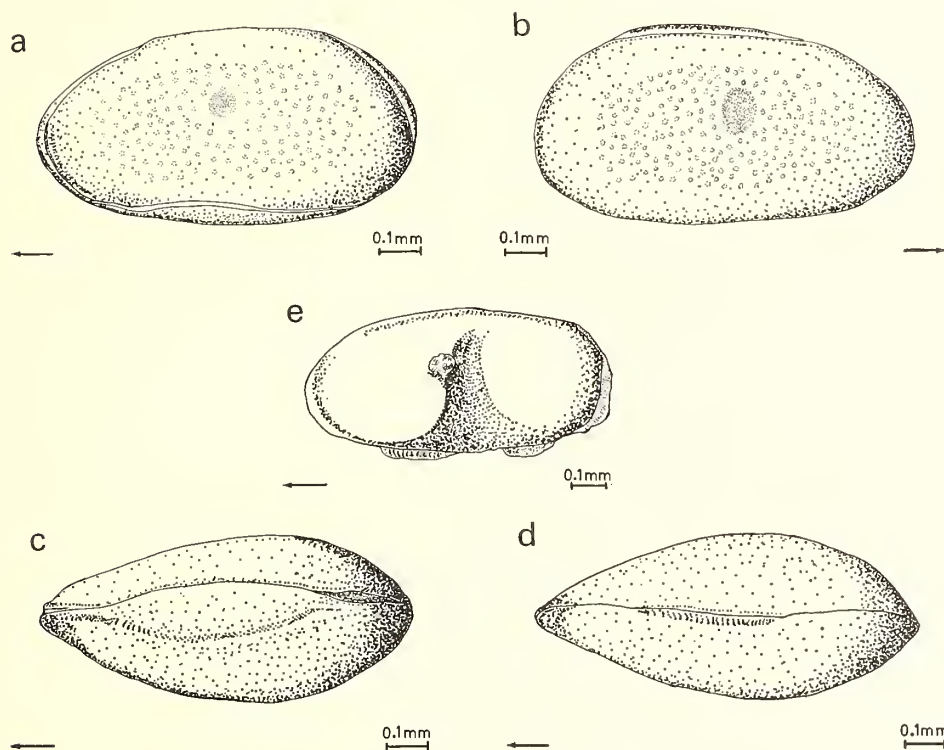
Holotype. Complete carapace, IO 2983. *Paratypes.* 4 complete carapaces, IO 2982 and IO 2984.

Occurrence. Holotype, IO 2983, *Geisina* Phase, Hopkins Band, Lower *A. modiolaris* Zone, Lower Coal Measures, Ryhope, Sunderland, Co. Durham. IO 2982, horizon as holotype, localities Washing-

ton and Follonsby, Co. Durham. IO 2984, shales above Flockton Thin Coal, Lower *A. modiolaris* Zone, Lower Coal Measures, Warncliffe Woodmoor Colliery, Doncaster, Yorkshire.

Dimensions. In mm.

	<i>Length</i>	<i>Height</i>	<i>Width</i>	<i>H/L ratio</i>
Holotype, IO 2983	1.04	0.55	0.43	52.8 %
IO 2982 <i>a</i>	0.98	0.50	0.40	51.0 %
<i>b</i>	1.02	0.54	0.42	53.0 %
IO 2984 <i>a</i>	1.07	0.57	0.47	53.2 %
<i>b</i>	1.06	0.55	0.46	52.7 %



TEXT-FIG. 9. *Carbonita claripunctata* sp. nov. *a-d*, paratype, IO 2984*a*, complete carapace. *a*, exterior left valve; *b*, exterior right valve; *c*, ventral view; *d*, dorsal view; *e*, internal mould showing furrow and muscle scar cast, from the *Geisina* Phase of the Hopkins Band, Ryhope Colliery, County Durham.

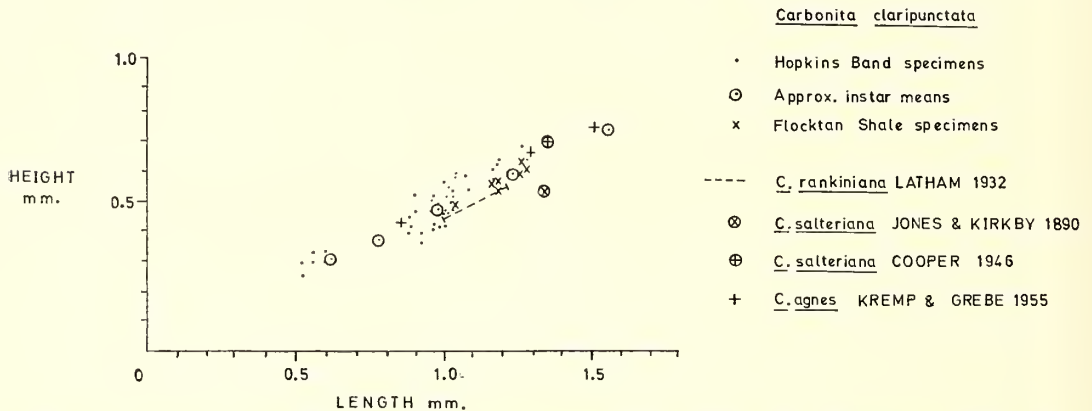
Description. Carapace elongate, sub-ovate, slightly tumid posteriorly. Dorsal margin straight or slightly convex, sloping posterior to anterior; ventral margin gently convex. Posterior end high, broadly rounded; anterior end low, bluntly pointed, with a steep antero-dorsal slope. External anterior margin of left valve bears a low ridge of thickening inside the overlap of the right valve; a similar thickening is present on the postero-ventral margin of the left valve. Greatest height and width posterior, dorsal outline broadly sub-ovate.

Hinge line straight, or arched slightly in lateral view, about half the length of the dorsal margin and mainly posterior. Left valve raised very slightly above right along the

hinge, and there is no groove. Right valve larger and overlaps the left narrowly on the ventral, anterior, and postero-dorsal margins. Shell surface coarsely pitted except over the muscle spot. These pits may tend to show a concentric pattern of arrangement. Muscle scar circular, antero-ventral of mid-point, with irregular secondary scars sometimes suggesting a rosette pattern. Internal ridge of shell thickening posterior to muscle scar well developed and leaving a characteristic furrow on internal moulds. A second fainter ridge is sometimes present anterior of the muscle scar.

Discussion. Dimorphism has not been detected in this species in the Hopkins Band, probably owing to the relatively small number of well-preserved specimens that were extracted.

In their original description of *Carbonia rankiniana*, Jones and Kirkby (1879) included both smooth and punctate forms from the Lower Carboniferous and Coal



TEXT-FIG. 10. Height and length dimensions of *Carbonia claripunctata* sp. nov. and allied or synonymous species.

Measures of Scotland and the Coal Measures of England. The new species proposed here is similar in lateral outline to the form they figure as fig. 2 and, like the shell of fig. 8, is punctate. Their figured specimens came from the Coal Measures at Provenhall in Lanarkshire, and material from that locality in the John Young Collection at the Hunterian Museum, Glasgow, undoubtedly belongs to *C. claripunctata* sp. nov. The new species was included in Jones and Kirkby's original broad definition of *C. rankiniana*. It differs, however, from *C. rankiniana* (sensu stricto) in lateral outline, the greatest height being nearer the posterior end, and in having a punctate shell. *C. rankiniana*, as recently restricted by Anderson (in press), is a smooth shelled Lower Carboniferous species.

Carbonia claripunctata sp. nov. differs from the Upper Coal Measures species *C. salteriana*, and the synonymous *C. roederiana* in shape, punctate shell, the ventral thickening of the shell, and in the presence of a well-developed internal ridge posterior to the muscle scar.

The form described and figured by Kremp and Grebe (1955) as *C. agnes* Jones from the Coal Measures of the Ruhr is similar to this new species in lateral outline, overlap, hinge characters, surface ornament, and size dimensions (text-fig. 10). The type species,

C. agnes Jones, although similar to *C. claripunctata* in size and surface ornament, differs in the arch of the dorsum and rounding of the ends. The German specimens should, therefore, more correctly be referred to *C. claripunctata* sp. nov. than to *C. agnes* Jones.

Stratigraphical distribution. Although the type material comes from the Lower *A. modiolaris* Zone of the Lower Coal Measures of Durham and Yorkshire, this species occurs in the Bottom Three Quarter ostracod band in the *C. communis* Zone of Durham. Scottish specimens are likewise from the Lower or Middle Coal Measures.

Kremp and Grebe (1955) recorded their synonymous form '*C. agnes*' as occurring sporadically throughout stages Westphalian A to Westphalian C in the Ruhr coalfield.

POSTSCRIPT

by F. W. Anderson

A complete revision of the genus *Carbonita* has been undertaken and is being prepared for publication. It was found necessary during the progress of this work to designate lectotypes for most of the species described by Jones (1870) and by Jones and Kirkby (1879).

In the foregoing paper Dr. Pollard has had occasion to refer to some of these species, and lectotypes are therefore here designated.

1. *Carbonita agnes* (Jones) 1870

Lectotype. In 43513, Adams Coll., Brit. Mus. (Nat. Hist.).

Horizon. Black Band Beds (*A. tenuis* Zone), Upper Coal Measures.

Locality. Cilfach Bargoed Colliery, Glamorgan, South Wales.

A holotype was not designated by Jones. The lectotype is from the type material and is the nearest to that figured by him (1870, pl. 9, fig. 6a).

2. *Carbonita evelinae* (Jones) 1870

Lectotype. In 56370, Adams Coll., Brit. Mus. (Nat. Hist.).

Horizon. Black Band Beds (*A. tenuis* Zone), Upper Coal Measures.

Locality. Cilfach Bargoed Colliery, Glamorgan, South Wales.

Holotype not designated by Jones (1870), but the original of his fig. 4a, pl. 9, is easily recognized in the type material and is here chosen as the lectotype.

3. *Carbonita humilis* (Jones and Kirkby) 1879

Lectotype. The specimen figured by Jones and Kirkby, 1879, pl. 2, fig. 14.

Horizon. Earl David's Parrot Coal (*A. modiolaris* Zone), Coal Measures.

Locality. Pirnie Colliery, Leven, Fife, Scotland.

The species was originally figured by Jones and Kirkby as *Carbonia jabulina* var. *humilis*. Several specimens still exist in the type material in the Brit. Mus. (Nat. Hist.) Collection but none of these can be identified with any certainty as that figured by Jones and Kirkby.

4. *Carbonita inflata* (Jones and Kirkby) 1879

Lectotype. I 1745, Brit. Mus. (Nat. Hist.) Coll.

Horizon. *A. modiolaris* Zone, Coal Measures.

Locality. Pirnie Colliery, Leven, Fife, Scotland.

The lectotype is one of the specimens figured by Jones and Kirkby (1879, pl. 2, figs. 15–19) as *Carbonia fabulina* var. *inflata*, probably fig. 15.

5. *Carbonita pungens* (Jones and Kirkby) 1879

Lectotype. I 1731, T. R. Jones Coll., Brit. Mus. (Nat. Hist.).

Horizon. Coal Measures, probably Lower *A. similis-pulchra* Zone.

Locality. Methil, Fife, Scotland.

The lectotype is taken from the type material and is the nearest to that figured by Jones and Kirkby (1879) as pl. 3, fig. 21.

6. *Carbonita rankiniana* (Jones and Kirkby) 1879

Lectotype. I 1741, Brit. Mus. (Nat. Hist.) Coll.

Horizon. Calciferous Sandstone Series, Lower Carboniferous.

Locality. Coast west of Pittenweem, Fife, Scotland.

The lectotype is one of the specimens figured by Jones and Kirkby (1879, pl. 3, figs. 1, 6, 7) from Pittenweem. Those on the same plate, from the Coal Measures at Provenhall, Glasgow, i.e. figs. 2–5, 8, are thought to be specimens of *C. salteriana* (Jones).

REFERENCES

- ANDERSON, F. W. Revision of the British species of the Carboniferous ostracod genus *Carbonita*. *Bull. geol. Surv. Gt Br.* (In press.)
- ARMSTRONG, G. and PRICE, R. H. 1953. The Coal Measures of north-east Durham. *Trans. Instn Min. Engrs.* **113**, 973–97.
- BEAN, W. 1836. Description and figures of *Unio distortus* Bean, and *Cypris concentrica* Bean, from the upper sandstone and shale of Scarborough; and *Cypris arcuata* Bean from the coal formation of Newcastle. *Mag. Nat. Hist.* **9**, 376–7, fig. 55.
- BÖGER, V. H. 1964. Palökologische Untersuchungen an Cyclothemen im Ruhrkarbon. *Paläont. Z.* **38**, 142–57.
- BROADHURST, F. M. 1964. Some aspects of the palaeoecology of non-marine faunas and rates of sedimentation in the Lancashire Coal Measures. *Am. J. Sci.* **262**, 858–69.
- CALVER, M. A. 1956. Die Stratigraphische Verbreitung der nichtmarinen Muscheln in den penninischen Kohlenfeldern Englands. *Z. dt. geol. Ges.* **107**, 26–39.
- 1966. In SMITH, E. G., RHYS, G. H., and EDEN, R. A. Geology of the country around Chesterfield, Matlock and Mansfield. *Mem. Geol. Surv. U.K.* (In press.)
- CARRUTHERS, R. G. 1930. Name, 'Hopkins Shell Bed'. *Mem. geol. Surv. Summ. Prog.* for 1929, p. 69.
- COOPER, C. L. 1941. Chester ostracods of Illinois. *Rep. Invest. Ill. St. geol. Surv.* **77**, 101 pp., 14 pls.
- 1946. Pennsylvanian ostracods of Illinois. *Bull. Ill. St. geol. Surv.* **70**, 177 pp., 21 pls.
- COPELAND, M. J. 1957. The arthropod fauna of the Upper Carboniferous rocks of the Maritime Provinces. *Mem. geol. Surv. Brch Can.* **286**, 24–28, pl. 1, 2.
- DAWSON, J. W. 1897. Notes on Carboniferous Entomostraca from Nova Scotia, in the Peter Redpath Museum determined and described by Prof. T. R. Jones and Mr. Kirkby. *Can. Rec. Sci.* **7**, 316–23.
- EAGAR, R. M. C. 1961. A summary of recent work on the palaeoecology of Carboniferous non-marine lamellibranchs. *C.R. 4^{me} Congr. Strat. et Géol. carbonifère, Heerlen*, **1**, 173–87.

- ECHOLLS, D. J. and CREATH, W. B. 1959. A survey of Mississippian, Pennsylvanian and Permian Ostracoda recorded in the United States. *Micropalaeontology*, **5**, 389–414.
- EDWARDS, W. and STUBBLEFIELD, C. J. 1947. Marine bands and other faunal horizons in relation to the sedimentary cycles of the Middle Coal Measures of Nottinghamshire and Derbyshire. *Q. Jl. geol. Soc. Lond.* **103**, 209–53.
- ERNST, W., KREJCI-GRAF, F., and WERNER, H. 1958. Parallelsierung von Leithorizonten im Ruhrkarbon mit Hilfe des Bor-Gehaltes. *Geochim. cosmochim. Acta*, **14**, 211–22.
- MICHELAU, P., and TASCH, K. H. 1960. Vergleich des Niveaus von Floz-Zollverein I mit dem von Wyshagen mit Hilfe der Bor-Methode. *C.R. 4^{me} Congr. Strat. et Géol. carbonifère, Heerlen*, **1**, 163–8.
- HARLTON, B. H. 1927. Some Pennsylvanian ostracoda of the Glen and Hoxbar Formations of southern Oklahoma and the upper part of the Cisco Formation of northern Texas. *J. Paleont.* **1**, 203–12, pl. 32, 33.
- 1928. Some Pennsylvanian ostracoda from Oklahoma and Texas. *Ibid.* **2**, 132–44, pl. 21.
- HARPER, F. and SUTTON, A. H. 1935. Ostracods from the Morrison Formation of the Black Hills of South Dakota. *Ibid.* **9**, 623–38, pl. 76.
- HEATH, R. J. 1961. The palaeoecology of the *pseudorobusta* Band, with a consideration of the lithology visible in hand specimen. *Unpublished M.Sc. thesis, Univ. of Manchester.*
- HENNINGSMOEN, G. 1953. Classification of Palaeozoic straight hinged ostracods. *Norsk geol. Tidsskr.* **31**, 185–288.
- HOLLAND, W. C. 1934. The ostracods of the Nineveh Limestone of Pennsylvania and West Virginia, Pittsburg. *Ann. Carneg. Mus.* **22**, 343–50, pl. 25.
- HOPKINS, W. 1927. Further modifications of the correlation of the coal seams of the Northumberland and Durham Coalfield. *Trans. Instn. Min. Engrs.* **74**, 221–53.
- 1928. The distribution and sequence of the mussel bands in the Northumberland and Durham Coalfield. *Proc. Univ. Durham. phil. Soc.* **8**, 1–14.
- 1960. 'Hopkins Shell Bed'. *Lexique Stratigraphique International, I Europe. Fasc. 3a VIII*, 183.
- JOHNSON, W. R. 1936. The ostracods of the Missouri Series of Nebraska. *Pap. geol. Surv. Neb.* **11**, 52 pp. pl. 1–5.
- JONES, T. R. 1870. On the bivalved Entomostraca from the Coal Measures of South Wales. *Geol. Mag.* (1) **7**, 218–19, pl. 9.
- 1884. Notes on the late Mr. G. Tate's specimens of Lower Carboniferous Entomostraca from Berwickshire and Northumberland. *Hist. Berwicksh. Nat. Cl.* **10**, 319, 325.
- 1885. On the ostracods of the Purbeck formation; with notes on Wealden species. *Q. Jl. geol. Soc. Lond.* **41**, 311–52, pl. 8, 9.
- 1889. Notes on Palaeozoic Bivalved Entomostraca No. 27. On some North American (Canadian) species. *Ann. Mag. nat. Hist.* (6) **3**, 373–87, pl. 16, 17.
- and KIRKBY, J. W. 1866. Some Carboniferous species. *Ibid.* (3) **18**, 32–51.
- 1867. On Entomostraca of the Carboniferous rocks of Scotland. *Trans. geol. Soc. Glasg.* **2**, 213–28.
- 1879. Some Carboniferous species belonging to the genus *Carbonia* Jones. *Ann. Mag. nat. Hist.* (5) **4**, 28–40, pl. 2, 3.
- 1884. On some Carboniferous ostracoda from Nova Scotia. *Geol. Mag.* (3) **1**, 356–62, pl. 12.
- 1886a. On some undescribed species of British Carboniferous ostracoda. *Ann. Mag. nat. Hist.* (5) **18**, 249–69, pl. 6–9.
- 1886b. On some fringed and other ostracods from the Carboniferous Series. *Geol. Mag.* (3) **3**, 248–53.
- 1886c. Notes on the distribution of the ostracoda of the Carboniferous formations of the British Isles. *Q. Jl. geol. Soc. Lond.* **42**, 496–514.
- 1890. On ostracoda found in shales of the Upper Coal Measures at Slade Lane, near Manchester. *Manch. geol. Min. Soc. Trans.* **21**, 137–42.
- and YOUNG, J. 1899. On *Carbonia*; its horizons and conditions of occurrence in Scotland, especially Fife. *Trans. Edinb. geol. Soc.* **7**, 420–42.
- KAUFMANN, A. 1900. Cypriden und Darwinulen der Schweiz. *Rev. suisse Zool.* **8**, 209–423.

- KELLETT, B. 1935. Ostracodes of the Upper Pennsylvanian and Lower Permian strata of Kansas. *J. Paleont.* **9**, 132-66.
- KESLING, R. V. 1951. Morphology of ostracod moult stages. *Illinois biol. Monogr.* **21**, 324 pp.
- KNAUF, W. 1963. Zur Microfauna im Oberkarbon der Bohrung Münsterland, 1. *Fortschr. Geol. Rheinld Westf.* **11**, 113-22.
- KNIGHT, J. B. 1928. Some Pennsylvanian ostracodes from the Henrietta Formation of Eastern Missouri. *J. Paleont.* **2**, 229-67.
- KREMP, G. and GREBE, H. 1955. Beschreibung und stratigraphischer Wert einiger Ostracodenformen aus dem Ruhrkarbon. *Geol. Jb.* **71**, 145-69, pl. 16.
- KUMMEROW, E. 1949. Über einiger Süßwasser-Ostracoden des Ruhrkohlen-Gebietes. *Nenes Jb. Miner. geol. Palaeont. Abh.* **9**, 45-49.
- 1953. Über oberkarbonische und devonische Ostracoden in Deutschland und in der Volksrepublik Polen. *Geologie*, **7**, 70 pp.
- LATHAM, M. H. 1932. Scottish Carboniferous Ostracoda. *Trans. R. Soc. Edinb.* **17**, 351-95.
- LEITCH, D., ABSALOM, R. G., and HENDERSON, S. M. K. 1937. The basal fauna of the Zone of *Anthraconaia modiolaris* in the Coal Measures of South Ayrshire. *Trans. geol. Soc. Glasg.* **19**, 404-8.
- MAGRAW, D., CLARKE, A. M., and SMITH, D. B. 1963. The stratigraphy and structure of part of the south-east Durham Coalfield. *Proc. Yorks. geol. Soc.* **34**, 153-208, pl. 19, 20.
- MANDELSTAM, M. I. 1956. Ostracods of the coal-bearing formations of the Kuznetsk Coalfield. (In Russian.) In *Atlas to guide forms of fossil fauna and flora of Permian formations of Kuznetsk Coal Basin*. VZEGEL, Moscow, 59-109, pl. 9-19.
- MARPLE, M. F. 1952. Ostracodes from the Pottsville Series in Ohio. *J. Paleont.* **26**, 924-40, pl. 133-5.
- MELVILLE, R. V. 1946. The non-marine lamellibranchs of the North Staffordshire Coalfield. *Ann. Mag. nat. Hist.* (11) **13**, 288-300.
- MURCHISON, R. I. 1839. *Silurian System*. London.
- PAYTON, C. E. and THOMAS, L. A. 1959. The petrology of some Pennsylvanian black shales. *J. sedim. Petrol.* **29**, 172-7.
- PRUVOST, P. 1911. Note sur les Entomostraces bivalves du terrain houiller du Nord de la France. *Annl. Soc. géol. N.* **40**, 60-80, pl. 1, 2.
- 1930. La faune continentale du terrain houiller de la Belgique. *Mém. Mus. Hist. nat. Belg.* **44**, 218-56.
- RAMSBOTTOM, W. H. C. 1952. The fauna of the Cefn Coed Marine Band in the Coal Measures at Aberbaiden, near Tondy, Glamorgan. *Bull. geol. Surv. Gt Br.* **4**, 8-32, pl. 2, 3.
- ROUNDY, P. V. 1926. Mississippian formations of San Saba County, Texas. Part II: The Microfauna. *Prof. Pap. U.S. geol. Surv.* **146**, 5-8, pl. 1.
- SCOTT, H. W. 1944. Permian and Pennsylvanian fresh-water ostracods. *J. Paleont.* **18**, 141-7, pl. 23, 24.
- 1961. In MOORE, R. C. (ed.) *Treatise on Invertebrate Paleontology*, Pt. Q: Ostracoda. *Geol. Soc. Amer. and Univ. Kansas Press*.
- and SUMMERSON, C. H. 1943. Non-marine ostracoda from the Lower Pennsylvanian in the southern Appalachians and their bearing on inter-continental correlation. *Am. J. Sci.* **241**, 653-71, pl. 1, 2.
- and WAINWRIGHT, J. 1961. In MOORE, R. C. (ed.) *Treatise on Invertebrate Paleontology*. Pt. Q: Ostracoda. *Geol. Soc. Amer. and Univ. Kansas Press*.
- SOHN, I. G. 1961. In MOORE, R. C. (ed.) *Ibid.*
- STRAND, E. (1926) 1928. Name *Carbonita* Strand. *Miscellanea Nomenclatoria Zoologica et Palaeontologica. Arch. Naturgesch.* **92**, 40, 41.
- SWAIN, F. M. 1955. Ostracoda of San Antonio Bay, Texas. *J. Paleont.* **29**, 561-646.
- TAYLOR, B. J. and CALVER, M. A. 1961. The stratigraphy of exploratory boreholes in the west Cumberland Coalfield. *Bull. geol. Surv. Gt Br.* **17**, 1-74.
- ULRICH, E. O. and BASSLER, R. S. 1906. Notes and descriptions of Upper Carboniferous genera and species. *Proc. U.S. natn. Mus.* **30**, 149-64, pl. 11.
- — 1908. New American Palaeozoic Ostracods; Preliminary revision of the Beyrichidae with descriptions of new genera. *Ibid.* **35**, 277-346, pl. 37-44.
- UPSON, M. E. 1933. The ostracoda of the Big Blue Series in Nebraska. *Bull. geol. Surv. Neb.* **8**, 1-54, pl. 1-4.

- VANGEROW, E. F. 1957. Mikropalaeontologische Untersuchungen in den Kohlschreider-Schichten im Wurmrevier bei Aachen. *Geol. Jb.* **73**, 457-97, pl. 20.
- WOOD, A. 1937. The non-marine lamellibranchs of the North Wales Coalfield. *Q. Jl. geol. Soc. Lond.* **93**, 1-22.
- WRIGHT, W. B. 1930. Additions to the fauna of the Lancashire Coal Measures. *Mem. Proc. Manchr. lit. phil. Soc.* **73**, 41-51, pl. 1.
- 1931. In *The Geology of Manchester*, *Mem. geol. Surv. U.K.*

Manuscript received 9 July 1965

JOHN E. POLLARD
Department of Geology,
The University,
Manchester 13.